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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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SUMMER MEETING PROGRAM

SOCIETY OF AUTOMOTIVE ENGINEERS INC
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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

To the Sections Officers

THE officers who have served the various Sections during the past year are at this time turning over their duties to newly-elected officers. The faithful services of the retiring officers are heartily appreciated, and those who will hold office during 1925-1926 have the best wishes of all for a prosperous year. A list of the incoming officers appears on p. 565 of this issue of THE JOURNAL.

Transportation Meeting Plans

THE Transportation Meeting Committee recently met in Philadelphia and decided to hold the Transportation Meeting in that city on Nov. 12 and 13. Arrangements are being made to have a group of well-qualified speakers discuss various factors involved in transportation, especially those pertaining to operation. An inspection trip will be included in the program of the meeting. Further details will be announced in the near future.

Production Meeting Plans

SEPT. 14, 15 and 16 have been chosen as the days on which the annual Production Meeting will be held. As previously announced, our cooperation with the American Society of Steel Treaters is an important feature of this meeting, especially inasmuch as the exhibition of machine-tool and heat-treating equipment of that organization is to be held during the period of the meeting.

The Society's Production Meeting Committee recently met in Cleveland and decided that the five sessions should be devoted to the subjects of machine tools, gears, training of mechanics and shop personnel and sheet steel and its fabrication and inspection.

Without doubt this will be the most successful Production Meeting that the Society has ever held. Special efforts will be made to entertain the ladies of the Society who may accompany their husbands to the Meeting.

Automotive Simplifications

ON p. 581 of this issue will be found the 29 reports of the Divisions of the Standards Committee that will be acted upon at the Standards Committee Meeting at White Sulphur Springs, W. Va. These reports are subject to approval by the Standards Committee and may receive extensive revision, or be referred back to the proper Divisions as a result of criticism submitted by Society members.

Although the reports, as approved by the Standards Committee, must be confirmed by the Council, at the Society business meeting, and by the voting members of the Society by letter ballot, the Standards Committee Meeting really presents the last practical opportunity for Society members or non-members to submit evidence in person or in writing to the effect that the recommendations do or do not meet the requirements of the industry. Lack of criticism of the reports at or before the Standards Committee Meeting can only be interpreted as indicating that the reports are in accord with good engineering practice and are satisfactory to the industry.

The Summer Meeting Approaches

AS the last days before the Summer Meeting pass in swift succession, plans are maturing rapidly; those that were vague become clear; those previously tentative become definite; and each day brings a goodly number of requests for accommodations at White Sulphur Springs, W. Va., where the Summer Meeting will be held, June 16 to 19.

More than 600 reservations have been made to date, and each mail brings still more applications. A blank was sent out with each of the two *Meetings Bulletins* that have recently been mailed to all members of the Society. If you are planning to attend the Summer Meeting and have not yet made your reservation, you are urged to fill out the application blank and mail it to us without further delay.

If you want to know just what is to be included in the program of the technical sessions, turn to p. 558 in this issue of THE JOURNAL where the program is given in full. You will find there many other details regarding the Summer Meeting, such as sports events; information about railroad schedules, connections and fares; automobile routes; and other items of interest. Take note that meetings of the Meetings, Research, Sections and Standards Committees will be held at White Sulphur Springs.

Another *Meetings Bulletin* will be published and

mailed about 10 days before the Summer Meeting. Be sure to read every word of it with extreme care, as that is our only way of getting any necessary changes, corrections, last-minute announcements or other important messages to all members of the Society. A certificate for making railroad reservations, with reduced-fare privilege, will be sent out with this *Meetings Bulletin*.

The Annual Nominating Committee

IN accordance with the Society's Constitution, the annual Nominating Committee of the Society shall consist of one Member of the Society to be elected from and by each Section of the Society prior to the Semi-Annual Meeting; and three Members of the Society who shall be elected at the business session of the Semi-Annual Meeting preceding the Annual Meeting at which officers are to be elected. These three members-at-large, no two of whom may reside in the same Section district, will therefore be elected at White Sulphur Springs, W. Va., at the business session, to be held on Tuesday evening, June 16.

The Sections have elected their representatives for the annual Nominating Committee, and in addition each Section has chosen an alternate to serve if for any reason the representative is unable to be present at White Sulphur Springs. The list of Section representatives and alternates is as follows:

Section	*Representative*	*Alternate*
Buffalo	J. W. White	John C. Talcott
Chicago	F. C. Mock	O. W. Young
Cleveland	Balfour Read	Ernest Wooler
Dayton	H. C. Mougey	W. A. Chryst
Detroit	George L. McCain	L. C. Hill
Indiana	O. C. Berry	Fred Duesenberg
Metropolitan	R. E. Plimpton	C. T. Myers
Milwaukee	F. M. Young	J. B. Armitage
New England	E. P. Warner	Ira D. Shaw
Pennsylvania	R. R. Whittingham	G. W. Gilmer, Jr.
Southern California	(Not yet elected)	
Washington	H. C. Dickinson	S. W. Sparrow

Southern California Section Launched

THE energy of the members of the automotive industry in and around Los Angeles and their keen interest in engineering matters are reflected in the formal inauguration of the Southern California Section of the Society at a meeting held at the City Club in the Pacific Coast metropolis on Friday evening, May 22. A news account of this meeting, at which President H. L. Horning was the principal speaker, will be found on p. 563 of this issue of THE JOURNAL.

Through the energetic efforts of Ethelbert Favary and other enthusiastic and loyal members, the Los Angeles Group has held regular meetings for the last 5 months at which many valuable papers have been presented, and finally a petition for the establishment of a regular Section, signed by more than 50 Members, was presented to the Council of the Society and a special visit to Los Angeles was made by President Horning to launch the Section. The occasion was made memorable by the cooperation of the Acting Mayor of the City of Los Angeles, the local Chamber of Commerce, local Motor Car Dealers Association, Service Managers Association, Automotive Council and the Automobile Club of Southern California. Such a handsome spirit of goodwill and helpfulness augurs well for the future of the new Section.

Service Problems Discussed

NUMEROUS advocates of the flat-rate system to customers and piecework for service-station employes were in evidence at the National Automotive Service Convention and Maintenance Equipment Show held in Detroit, May 20 to 23, under the auspices of the National Automobile Chamber of Commerce with the cooperation of the Society, Motor & Accessory Manufacturers Association, Automotive Equipment Association, National Automobile Dealers Association, Automotive Electric Association and Automotive Manufacturers Association. It was noted that at least 75 per cent of the service-men present at one of the important sessions were operating under this plan and that it was yielding very satisfactory results.

Among the other items of predominant interest, the question of suitable education of mechanics and shop personnel was emphasized, both at a session devoted principally to this topic and at a conference where the Education Committee of the Chamber presented its proposals for cooperation in education between industrial organizations and schools.

A notable feature of the meeting was the frankness with which the various speakers discussed their specific practical problems. With this attitude in evidence, a meeting cannot fail to redound to the benefit of all concerned.

An unexpected but very timely element was introduced by E. V. Rickenbacker who made a number of very interesting predictions concerning the development of aviation in this Country. He emphasized the fact that aviation must succeed because it introduces into our transportation system an element that is superior to others in many respects, in that it fulfills needs that are not otherwise satisfied.

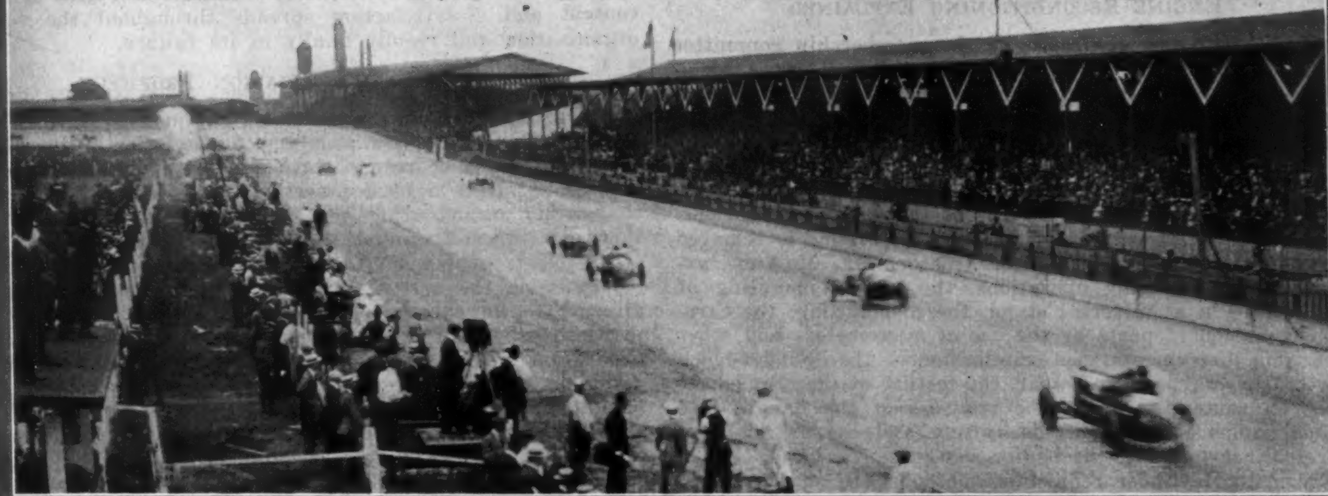
Great credit is due the Service Committee of the National Automobile Chamber of Commerce, and especially H. R. Cobleigh, for arranging such a profitable meeting and exposition of maintenance equipment. Both the technical sessions and the Maintenance Equipment Show were well attended by persons who were vitally interested from a very practical standpoint.

A detailed account of the Convention will be found on p. 553 of this issue of THE JOURNAL.

THE LEADER

THE leader of men has been loosely called a genius or an accident. The truth is that he is an expert in herd reactions, an intuitive psychologist. The man with a gift for leadership has inherited a knowledge of how society, that machine created by the master of all craftsmen, will respond to certain stimuli in accordance with unvarying laws. Instinctively he exerts this knowledge and draws thousands shouting in his train.—D. O. Edson.

MEETINGS OF THE SOCIETY



SERVICE AT A PROFIT

Keynote of Successful Convention; Valuable Papers and Exhibition Featured

Milking stools seem to have no connection with automotive maintenance, but the National Automobile Chamber of Commerce Service Committee through A. B. Cumner utilizes this homely symbol to illustrate the factors involved in satisfactory service. The top of the stool that was exhibited at the National Automotive Service Convention and Maintenance Equipment Show in Detroit, May 20 to 23, represented "square deal and satisfaction"; the three legs represented respectively the maker's responsibility, the dealer's responsibility and the owner's responsibility. Through the lack of any one of these items the square deal and satisfaction would not be supported.

W. M. Warner, vice-chairman of the Service Committee of the Chamber, in outlining the purpose of the national convention, stated that the object of service-men should be to raise the standard and to lower the cost of service. The capacity rather than the number of service-stations should be increased by the use of labor-saving devices and appropriate tools.

Maintenance Equipment Show

One of the most valuable features of this year's event was the exhibition of maintenance equipment for service stations. Mr. Warner called attention to the fact that over 100 exhibits, representing at least 80 per cent of the maintenance equipment industry, were displayed. Hundreds of service-men took advantage of the opportunity to inspect the equipment, much of which was in actual operation.

Included in the exhibit was a booth containing examples of the work of the Standards Committee and Department of the Society of Automotive Engineers. The display included samples of the following S.A.E. Standards: Starting-motor cable, armored wire, rubber bushings, fuses and fuse clips, generator terminals, starting-motor terminals, storage-batteries, fuel and lubrication tube fittings, poppet valves, spark-plugs, carbureter flanges, annular ball-bearings, rod ends and pins, screws, bolts and nuts, lubricating oils, wire cloth, brake-lining, lock washers, cotter pins, seamless steel tubing and copper tubing. Among the items included in the Recommended Practice group were pressure-gage connections, piston rings and grooves, felts and fan belts.

An important feature of the Society's exhibit was historical material showing the growth of automotive standards since the Association of Licensed Automobile Manufacturers report on screws, dated March 1, 1906, up to the present specifications and standards as found in the S.A.E. HANDBOOK.

The Convention and Show were managed by the National Automobile Chamber of Commerce with the cooperation of the Society of Automotive Engineers, Motor & Accessory Manufacturers Association, Automotive Equipment Association, National Automobile Dealers Association, Automotive Electric Association and Automotive Manufacturers Association.

Personal Equation Important

Among the most vital factors involved in satisfactory service, Howard A. Coffin, assistant to the president, Cadillac Motor Car Co., mentioned the human element. Although Mr. Coffin was not able to be present, the paper was read very creditably by H. R. Cobleigh, secretary of service, National Automobile Chamber of Commerce. In Mr. Coffin's opinion, faulty human contact means inevitable failure. He believed that service men could well utilize the Rotary Club motto, "He profits most who serves best."

In opening the discussion of Mr. Coffin's paper, Dr. M. W. Franklin of the General Motors Export Co., called attention to the fact that the fundamental principles involved in service are the same at home and abroad.

The difficulties involved in service at a distance are such that foreign service-men must be well educated and they must be good enough mechanics so that they will refrain from diagnosing a car's ills immediately upon its appearance. These men must be equipped with sales ability and they must in addition have business instincts and capabilities as organizers.

Service-Station Management

Principal among the items advocated for a successful service-station, as mentioned by J. E. Mills, service manager of the Packard Company's Detroit branch, were: (*a*) cleanliness of the building, both on the interior and on the exterior; (*b*) prompt greeting of the customer; (*c*) a courteous, polite and friendly spirit; (*d*) definite delivery promised and maintained; (*e*) prompt, efficient, careful and accurate workmanship; (*f*) prices definitely standardized; (*g*) accurate billing and (*h*) few arguments.

Mentioning the budget as a pre-determined plan for doing business, Mr. Mills dealt extensively with methods for arriving at a satisfactory budget estimate and for applying the budget system as a benefit to the conduct of the station. He used approximate figures to show the items of labor, materials, equipment and the factors involved in overhead. Sample record charts demonstrated the possibilities of using graphical records to show the various tendencies, and it was

pointed out how such records could be utilized in the prediction and the regulation of the business.

Engine Reconditioning Explained

R. C. McWane, chairman of the membership committee of the National Motor Regrinders and Rebuilders Association, presented a very comprehensive paper, descriptive of methods and equipment used in his service-station. He stated that the success or failure of an engine-reconditioning job might be well summed up in the one word, alignment. This involves the skillful use of tools and equipment for measuring and controlling the results of the various operations.

Tracing the process from the time the engine is removed from the automobile, truck or tractor, Mr. McWane explained the cleansing operations, the proper mounting of the engine in a universal stand, the dismantling, the careful inspection of parts by the use of micrometers and other precision instruments, the examination of the cylinder-block for cracks, warpage and wear, the testing of the crankshaft between centers to check the trueness of the flanges and to determine if the shaft is sprung and the examination of all other parts of the engine.

Regarding cylinder refinishing methods, the speaker mentioned boring, grinding, reaming and honing. He reviewed the advantages and the disadvantages of each of these processes and in connection with honing made reference to a survey made in 1924 by the Research Department of the Society of Automotive Engineers showing that, of 24 well-known makers of automobiles and engines, 12 were honing the cylinders, 9 were finish-grinding them, while the remaining 3 were using the lapping process. Mr. McWane recommended regrinding as the best method to use in the reconditioning of automobile-engine cylinders.

Satisfactory methods and equipment for fitting bearings were discussed at some length.

Metallurgical Factors Discussed

L. A. Danse, of the Cadillac Motor Car Co., explained some of the reasons why bearings should be constituted of materials that are heterogeneous in their make-up. Bronze, for example, offers a very satisfactory bearing metal owing to the fact that it is composed of a soft matrix with hard crystals distributed throughout. The speaker emphasized the importance of establishing a good bond between the bronze backing and the babbitt bearing surface. In cases where this bond is not complete, an oil-film is established between the bronze and the babbitt, and, because this film does not conduct heat satisfactorily, the babbitt is not cooled sufficiently and it melts. A good bearing metal was said to be constituted of 91 per cent of lead, 4½ per cent of antimony and 4½ per cent of copper. Many unsatisfactory substitutes were said to exist.

Mr. Danse advocated the use of a one-tooth reamer with a sharp cutting edge and a pronounced rake. Oil grooves should be as few as possible, should stop short of the sides of the bearings and should have the edges broken toward the direction of rotation so as to prevent the breakage of the oil-film.

Service in Industry

E. V. Rickenbacker, vice-president of the Rickenbacker Motor Co., emphasized the importance of coordinating the engineering and service departments, this need for cooperation applying to both field and factory representatives. Further standardization would be of great assistance to all concerned. According to the speaker the factories should not sell a carload of automobiles to a new man and consider him forthwith a full-fledged distributer. In all fairness to the distributer, the factory should assume a definite responsibility in helping him to succeed by informing him fully of the factors involved in his business and by assisting him in every possible way.

Service-managers or, as Mr. Rickenbacker preferred to call them, maintenance managers, should be of the booster variety. Manufacturing problems and complications should not be revealed to salesmen because of the possibility of their losing faith in the product. The service-manager should make his criticisms in the proper spirit to the factory and not to the car-owner, for otherwise a spirit of discontent and dissatisfaction spreads throughout the whole organization and results finally in its failure.

Rickenbacker's Aviation Prophecy

Diverging from his discussion of automotive service, Mr. Rickenbacker outlined a prophecy for aviation. He stated that this means of transportation would inevitably succeed because it offers a needed service, it is faster and better than other means of transportation and is the only type that can proceed around the world without calling upon other means of transportation for assistance.

Discussing the matter of personnel capable of operating aircraft to an extent comparable with that prevailing at present with automobiles, the speaker stated that the new generation will have little fear of air travel and that individuals in this new generation will be keyed up, physically, mentally and nervously, to the point where they can utilize aircraft with a reasonable degree of safety, at least equal to that applying to the use of automobiles today.

Reminiscing, Mr. Rickenbacker mentioned the fact that he and others were considered heroes some 20 years ago because they dared to drive an automobile. Within a quarter of a century, this practice has become commonplace, just as the flying of aircraft will become commonplace 25 years hence. At that time, said Mr. Rickenbacker, the aircraft industry will far outstrip the present size of the automotive industry.

The first step in this development is at present in progress and involves the carrying of freight, express and mail by heavier-than-air craft. This step will be followed by others leading to the final point of the extensive private application of the new means of transportation that will greatly increase wealth and values because of the great increase in accessibility of property and resources.

A 5000-Ft. Airship

Capt. Rickenbacker visualized conditions 25 years hence when lighter-than-air craft, 5000 ft. in length, will remain in the air and in motion around the world without landing for a year at a time. Heavier-than-air craft will be utilized on feeder lines to the principal cities where smaller dirigibles will serve as lighters to carry relief crews, passengers, rations and equipment to the liners as they approach the main centers. The small dirigible will proceed to the larger craft, it will anchor to the craft in motion and the necessary exchange of cargo will be accomplished without interruption to the voyage. The smaller craft will then return to its point of departure. It was believed by the speaker that 90 per cent of those present in the audience would live to see this accomplishment.

Flat Rates Advocated

Among those who come to a maintenance station, Don T. Hastings of Williams & Hastings, Detroit, mentioned new owners who return for "something for nothing," old owners whose cars are beyond the warranty period, those who have purchased their cars through other stations and transients.

Why does an owner visit a particular maintenance station? The following 12 reasons were given for this: (*a*) advertising, (*b*) cleanliness of station and equipment, (*c*) courtesy, (*d*) friendliness, (*e*) guarantee, (*f*) habit, (*g*) interest in owner's welfare, (*h*) technical knowledge, (*i*) suitable location of the shop, (*j*) reasonable prices, (*k*) satisfactory quality of work and (*l*) speed of accomplishment.

Regarding the advertising, Mr. Hastings stated that billboard advertising proved to be too expensive and that the results from newspaper advertising and from circular letters were not very satisfactory. Telephone-directory advertising was said to pay because of its appeal to transients. The best advertisement, however, was said to be a good reputation for satisfactory maintenance.

Fully 90 per cent of the grievances registered by patrons were laid to psychological factors. Salesmen and service-

men should be capable of handling these cases. Many complaints may be avoided by a careful follow-up at definite intervals by telephone.

Team Competition Successful

Mr. Hastings strongly advocated the application of the flat-rate system to customers, with piecework in the shop. He explained how competitive methods have been applied in his shop to the advantage of all concerned. This method involves the division of the personnel into two teams, the two men who have received the highest earnings within a 2-week interval become captains of the teams; a 5 per cent bonus is granted to the team having the highest earnings for the period during which the competition lasts, and then the teams are changed.

By this method, horseplay has been banished from the shops, better cooperation exists and the less satisfactory workmen are automatically eliminated.

Actual Figures Given

Mr. Hastings was commended by the chairman of the meeting for his willingness to present the accompanying set of figures, representing financial matters in his shop for the year 1924.

F. A. Bonham, of the Durant Motor Car Co., stated that the objective toward which every service-station should strive should be to maintain the cars so as to keep them running the greatest number of useful hours, this in contradistinction to the attitude of repairing cars after they become broken or damaged.

Another Flat-Rate Advocate

Flat rates to customers and piecework in the shop were strongly recommended by William G. Gow, general service manager of the Studebaker Sales Co., Newark, N. J., in his paper entitled Making a Success of Flat Rate and Piece Work. In part Mr. Gow's remarks were:

> We now approach the period of piecework or what I might term as the era of the service-manager's paradise. This is the era of system, routine, order, no idle time, no overtime, intelligent management, one price to the customer, one price to the mechanic, good working conditions and better paid productive and nonproductive help, in other words, buying labor by the job and selling it by the job.
>
> Under the time and material method for repairs, the car-owner pays for labor by the hour and the shop pays the mechanics for their labor by the hour. It is something like the huckster who buys potatoes by the bag and sells them by the pound, with the exception that the huckster has *no idle potatoes*. The mechanic paid at the hourly rate receives from 40 to 60 per cent of the rate charged to the customer and the difference goes to pay for the overhead expense, mechanic's idle time, which cannot be charged for, come-back jobs and a variety of other expenses.
>
> With a piecework job, in which is priced the material used on every operation down to the last cotter pin, the customer is charged a certain amount for the complete operation. From this amount is given a fixed price to the mechanic, a like amount for overhead, a charge for the new parts used and an amount that is used for incidentals necessary to complete the job, such as cotter pins, rags and gasoline. The mechanic's price is fixed regardless of the time it takes him to do the job, but the average operation shows that the mechanics can almost cut the time given in half. This means that he can accomplish 14 hr. work in an 8-hr. day. This truly is an incentive to work for. The mechanic must bear in mind, at all times, that his work is guaranteed for a period of 30 days.

FIGURES ON SERVICE-STATION OPERATION PRESENTED BY MR. HASTINGS

Income	
Labor Sales Outside	$52,342.73
Labor Sales House	35,274.93
Labor Sales Total	87,617.66
Cost of Labor	35,891.23
Gross Income from Labor	51,726.43
Labor Cost, Per Cent of Sales	38.9
Net Income, Washes	$404.67
Profit on Outside Jobs	2,639.83
Profit on Salvage	354.88
Profit on Oil and Grease	1,305.40
Miscellaneous Income	3,570.68
Total Income	$60,001.89
Expenses Direct	
Salaries	$23,402.83
Heat, Light, Power and Telephone	612.48
Maintenance of Tools and Equipment	2,120.70
Lost Time	1,066.68
Depreciation on Equipment	3,881.18
Supplies and Miscellaneous	6,520.13
Insurance	247.19
Total	$37,851.19
Gross Profit	$22,150.70
Overhead Charged to Shops 15 Per Cent[1]	14,819.22
Net Profit	$7,331.48
Net Profit, Per Cent of Total Income	12.2

[1] All items are analyzed in arriving at this.

E. V. Rickenbacker

H. A. Coffin

William G. Gow

L. Clayton Hill

Authors of Four of the Papers Presented at the Service Meeting

This contract between the service-station and the mechanic is lived up to the letter of the law. That is necessary, because a written guarantee is given the customer on his invoice that the work is guaranteed for that period of time. The only cases where the mechanic is not held responsible is when the part installed proves defective. This charge is assumed by the service-station.

We found that the use of foremen was unnecessary inasmuch as the work was given a thorough test by the tester and the job was, in addition, guaranteed by the mechanic. In this way any work improperly completed would be detected before the car reached the owner's hands. . . . . . .

I know from results and facts that piecework is a good, safe and profitable system for three reasons. First, we have satisfied customers; this I have found by personal contact and by letters. Second, we are making money; this I have found by our monthly reports. Third, we have satisfied and happy mechanics; this I have found because the men in my shop have informed me that, if we ever tried to go back to the hourly rate, every one of them would quit.

Mr. Gow accompanied the presentation of his paper by slides that showed the methods devised by him for keeping satisfactory records in his shops and for controlling the work in a business-like manner. Great interest was shown in these records that were unique in many respects.

The paper was discussed very interestingly by Joseph Kenney, president of the Brooklyn (N. Y.) Service Association.

The Service Sales Manager

With the idea of emphasizing the need of salesmanship in service, C. E. Gambill, president of the National Automobile Dealers Association, advocated that service-managers should in reality be called service sales managers. The shops must be kept busy, which means the application of sales effort of the highest type. Assuming that a given service-station is now handling only 40 per cent of the work that should come to it, steps should be taken to obtain the remaining 60 per cent that is now carried on in the so-called alley shop.

Mr. Gambill stated that in his shop the flat-rate system for owners and piecework for mechanics is in effect. Forty per cent of the returns go to the mechanic and 60 per cent are applied to overhead and profit. The speaker advocated the elimination of free service from the picture. He emphasized the need for courtesy and the use of proper methods by all contact men.

F. J. Wells, service-manager of the Pierce-Arrow Motor Car Co., suggested that schools for service-managers should be established.

C. A. Vane, general manager of the National Automobile Dealers Association, was among those who discussed Mr. Gambill's very interesting address. It developed during the discussion that approximately 75 per cent of the service-men present at the session were operating on the flat-rate piecework basis.

Training of Personnel

At an interesting conference on educational methods in the training of personnel, conducted under the chairmanship of H. E. Repasz of the Willys Overland Co., the Education Committee presented its report covering a proposed plan for greater cooperation between educational institutions and the industry. Among other items included in this program was the suggestion that all manufacturers make available to the Committee complete service data pertaining to their product and that other equipment be supplied for authorized educational institutions. Inasmuch as the plan was only tentative, the Committee requested that discussion of the various factors be submitted and that the manufacturers define their attitude toward the proposal which mentioned a certain minimum time that should be devoted to the education of mechanics.

F. C. Smith, superintendent of Young Men's Christian Association Schools; Mr. Ambrose, of Carnegie Institute; Dr. M. W. Franklin, General Motors Export Co.; and Mr. Norton, of the Education Committee of the Chamber, participated in the discussion.

Maintenance Most Important Factor

"There has always been a shortage of good mechanics capable of carrying on a maintenance division," said J. F. McDonald, service-manager of the Ohio Buick Co., in his address on training repair-shop personnel. He believed that the distributer should assume the responsibility of properly training men for shop work and outlined a plan that is being followed by his company in its training course. Briefly, the course embraces a schedule of 14 periods throughout the year, at which the important elements of an automobile are discussed in general and the various operations are studied and demonstrated in detail. The average attendance at these periods is about 225 men who represent the personnel of the Cleveland station, as well as dealer organizations from surrounding towns.

One of the most interesting periods is that devoted to tool equipment. On certain occasions, some 200 tools for various operations have been displayed, and representatives from the various departments take pride in submitting tools of their own design for the consideration of those in attendance. The details of the apprenticeship system employed by Mr. McDonald's establishment were explained.

Repainting Sells Used Cars

One of the most interesting and instructive papers presented during the meeting was that by L. Clayton Hill, automotive sales manager of Valentine & Co., entitled Repainting Used Cars To Increase Their Salability.

Mr. Hill based his address on the premise that the condition of the finish of any used vehicle is a most important factor in determining the salability of that vehicle. The average buyer of used cars in general selects the car that appeals most to his eye. Most dealers who have made a notable success in marketing used cars are following the policy of repainting all jobs that are not in good condition.

Owing to the genius of the paint chemists, the dealer now has at his command painting materials of the nitro-cellulose type and suitable methods of application that are many times more rapid than those available in the past. From between 2 weeks and 1 month, the required time for repainting has been reduced to 1 or 2 days under ideal conditions, and the resulting finish will have double or treble the life of the best repaint job of former years.

The nitro-cellulose system, described in detail by Mr. Hill, is known as the full nitro-cellulose system as distinguished from the partial nitro-cellulose system. In this class, all materials used in repainting are of the nitro-cellulose type and are quick drying in their nature. Forced drying or long air-drying periods are avoided, and the system once applied forms a homogeneous whole.

Owing to the fact that the solvents in all nitro-cellulose lacquers contain materials that act as ideal paint removers, it was recommended that in no case should the nitro-cellulose lacquers be applied over the old paint. It is essential that the job be satisfactorily stripped and that a perfectly clean surface be left for the application of the lacquer. A number of methods of stripping and cleaning were described in detail by the speaker.

As for painting, the lacquers must be applied by an air brush or spraying system, inasmuch as application with a brush would be too slow, on account of the quick drying character of the liquid. Suitable precautions against fire should be taken, as the evaporated solvent forms a combustible mixture with the surrounding air. Exhaust systems and hoods are provided for this work, and no difficulties are experienced when conditions are properly maintained.

The priming coat forms the foundation of the system. It air-dries at normal room temperature in 30 min., when the next coat may be applied. The second coat or "gunglaze" is applied over the primer and forms a perfect surface on which the enamel may be sprayed. The gunglaze pos-

sesses filling properties and may be applied in two or three coats as required. It dries overnight. Nitro-cellulose spot putty may be used for covering screw heads or surface defects; it may be applied over the gunglaze or over the primer coat as preferred. The third and final material used in the complete nitro-cellulose system described is the nitro-cellulose finishing enamel. Two or three coats of this enamel are usually sufficient and, on account of the rapid drying properties, all enamel coats may be applied in 1 hr.

A unique advantage claimed for the system described is the practicability of applying varnish over the nitro-cellulose materials in cases where a very high luster is desired. Suitable methods for rubbing and polishing by the use of polishing liquids were outlined briefly.

An interesting phase of Mr. Hill's paper pertained to experimental work now in progress in the laboratory of the company that he represents to perfect a masking or screening liquid that is non-soluble in nitro-cellulose solvents but soluble in water. This liquid is intended for brushing over the surfaces to be protected from the lacquer, as a replacement for the paper or cardboard masks ordinarily used. Upon completion of the painting, this screening liquid can be washed off readily with water.

Attention was called to the fact that oil and grease are enemies of any nitro-cellulose material, and for this reason it is sometimes not desirable to attempt the painting of chassis parts, such as springs, axles and frames, with nitro-cellulose lacquers. Suitable satin-gloss chassis-finishing enamels of the waterproof-varnish type were said to be much safer.

During Mr. Hill's talk, Russell Rogers, production engineer in the Detroit office of Valentine & Co., demonstrated the application of each of the materials of the complete nitro-cellulose system and also applied the whole system to a portion of an automobile body. The application of nitro-cellulose enamel over an old black baked enamel surface was also shown.

Great interest was shown in the demonstration and after the session many of the audience took advantage of the opportunity to inspect the compressed-air apparatus and spraying equipment.

SUCCESSFUL SUMMER MEETING ASSURED

Interesting Technical Sessions and Attractive Recreational Features Promised

Unless all signs fail, the events of June 16 to 19 will be remembered by nearly 1000 members of the Society and guests among the most pleasant of their experiences. Up-to-the-minute technical discussions on a variety of subjects, recreational and sports activities and an opportunity for pleasant and profitable contact among the members will be the principal attractions offered by the Summer Meeting at White Sulphur Springs, W. Va.

The plans for various events have been circulated in two issues of the *Meetings Bulletin* that have gone forward to all the members. Approximately 10 days before the meeting, a third *Meetings Bulletin* will be issued in order that all may be informed concerning the final arrangements. On p. 558 of this issue of THE JOURNAL will be found a program outlining the highspots of the meeting.

NOISE INVESTIGATION

H. C. Snook will present a paper on Automobile Noise Measurement that will deal with the detection, location and diagnosis of noise phenomena. No one is better qualified to discuss this problem, and a most interesting and spectacular presentation accompanied by an elaborate demonstration of methods and apparatus is assured.

LUBRICATION AND FUEL UTILIZATION

Factors in engine and cylinder lubrication, including temperature effects, will be discussed in detail by A. Ludlow Clayden, who has made an extensive series of dynamometer tests with varying cylinder-wall and oil temperatures. Steam cooling has been used to obtain high operating-temperatures.

A most interesting series of motion pictures demonstrating the mechanism of lubrication will be shown by D. P. Barnard, 4th, in connection with the presentation of his paper on Oil Flow in Complete Journal Bearings. The motion picture clearly indicates the manner in which the oil functions

ENTRANCE TO THE GREENBRIER HOTEL, WHITE SULPHUR SPRINGS, W. VA.
This Palatial Hostelry Will Be the Center of the Summer Meeting Activities, the Sessions This Year Being Scheduled for June 16 to 19 Inclusive

as a lubricant under various conditions of pressure and speed.

The Cooperative Fuel Research has been productive of many interesting results in the last few months. These will be outlined in a paper by J. O. Eisinger of the Bureau of Standards.

Highway Safety

Safe driving insofar as other vehicles and pedestrians are concerned requires but one rule, namely, that a vehicle shall always be capable of stopping within the *clear view ahead.* Dr. H. C. Dickinson will explain the safety factors incorporated in his *Driving Rules,* and will have a demonstration to illustrate his points.

Secretary of Commerce Hoover or his representative will be present at the Highway Safety Session to interpret the automotive features of highway safety that were emphasized in the recent report of the National Conference on Street and Highway Safety.

C. F. Kettering will address the session on automobile design and construction features as elements in highway safety. This address will presumably include a discussion of such items as brakes and headlighting.

Gasoline-Electric Motorcoaches and Rail-Cars

Present practice in the design of rail-cars with the mechanical drive and with the gasoline-electric drive will be outlined by C. O. Guernsey, who will also speak of the advantages and disadvantages of these types, giving a comparison of the relative costs, weights and performance.

Engineering details pertaining to an electric drive for gasoline motorcoaches will be treated by H. S. Baldwin in a very comprehensive paper covering the various steps in the development of this type of drive.

Riding-Qualities

A very interesting demonstration and paper pertaining to Elementary Dynamics of Automobile Spring-Suspension will be given by F. C. Mock. The action of different suspension types will be carefully analyzed and illustrated by the use of models.

In judging riding-qualities, should displacement, velocity,

SUMMER MEETING HIGHSPOTS

Time and Place

The Summer Meeting will be held in and about the Greenbrier Hotel and its cottages, White Sulphur Springs, W. Va., June 16-19. Adequate hotel, sports and meeting facilities are available. Special hotel and railroad rates.

Tuesday, June 16

Morning.—Registration and assignment to rooms; also registration for sports events

Afternoon.—Sports events and special entertainment
Ladies' reception

Evening.—Noise Investigation Session
Automobile Noise Measurement—H. C. Snook, Bell Telephone Laboratories, Inc. An elaborate demonstration of methods and apparatus will accompany Mr. Snook's address
Semi-Annual Business Meeting
Motion Pictures
Dancing

Wednesday, June 17

Morning.—Lubrication and Fuel Utilization Session
Cylinder and Engine Lubrication—A. Ludlow Clayden, Sun Oil Co.
Oil Flow in Complete Journal Bearings—D. P. Barnard, 4th, Standard Oil Co. of Indiana. Mr. Barnard will show an extremely interesting series of motion pictures that demonstrate the mechanism of lubrication in a glass bearing
Recent Results of the Cooperative Fuel Research—J. O. Eisinger, Bureau of Standards
Sports events and special entertainment for ladies

Afternoon.—Sports events and entertainment

Evening.—Highway Safety Session
Driving Rules—H. C. Dickinson, Bureau of Standards
Highway Safety Factors—Hon. Herbert Hoover, Secretary of Commerce, or his representative
Automobile Design and Construction Features as Elements in Highway Safety—C. F. Kettering, General Motors Research Corporation
Motion Pictures
Dancing

Thursday, June 18

Morning.—Gasoline-Electric Motorcoach and Rail-Car Session
Requirements in Rail-Car Design—C. O.
An Electric Drive for Gasoline Motorcoaches—H. S. Baldwin, General Electric Co.

Afternoon.—Research Committee Meeting
Standards Committee Meeting
Field Day and Other Sports Events
Special entertainment for ladies

Evening.—Sections Committee Meeting
Riding-Qualities Session
Elementary Dynamics of Automobile Spring-Suspension—F. C. Mock, Stromberg Motor Devices Co., Inc.
Riding-Qualities of Motor Vehicles—R. W. Brown, Firestone Tire & Rubber Co.
Motion Pictures
Grand Ball

Friday, June 19

Morning.—Brake Session
Fundamentals of Brake Design
O. M. Burkhardt, Research Manager, Society of Automotive Engineers
Development of a Modern Four-Wheel Mechanical Braking System—J. R. Cautley and A. Y. Dodge, Bendix Brake Co.
Hydraulic Brakes, Engineering Factors in Their Design and Construction—H. E. Maynard, Chrysler Motor Corporation

Afternoon.—Transmission Session
Recent Work on Unconventional Transmissions—P. M. Heldt, *Automotive Industries.* Numerous examples of new transmissions will be displayed, explained and demonstrated
A Study of the Probable Sources of Transmision Noise—Earle Buckingham, Niles, Bement, Pond Co.
Conclusion of Sports Events

Evening.—Motion Pictures
Dancing
Departure of Special Trains

Exhibition and demonstration of equipment and apparatus will be features of practically all sessions

Summary Meeting Train Schedule

(ALL TRAINS OPERATE ON STANDARD TIME)

Western Trains

GOING June 15			RETURNING June 20	Railroad Fares: Fare and a Half Round Trip	Railroad Fares: Tourist Round Trip
Lv. Chicago	1:00 p.m.	Big Four	Ar. 4:55 p.m.	$34.47	$41.40
Lv. Detroit	1:50 p.m.	Big Four	Ar. 1:20 p.m.	28.05	33.65
Lv. Toledo	3:40 p.m.	Big Four	Ar. 11:30 a.m.	24.95	29.93
Lv. Cleveland	4:00 p.m.	Big Four	Ar. 4:55 p.m.	29.49	30.90
Lv. Indianapolis	6:15 p.m.	Big Four	Ar. 11:50 a.m.	25.01	30.11
Lv. Dayton	8:05 p.m.	Big Four	Ar. 10:00 a.m.	22.02	26.53
Lv. Cincinnati	9:45 p.m.	Chesapeake & Ohio	Ar. 6:20 a.m.	19.08	23.00

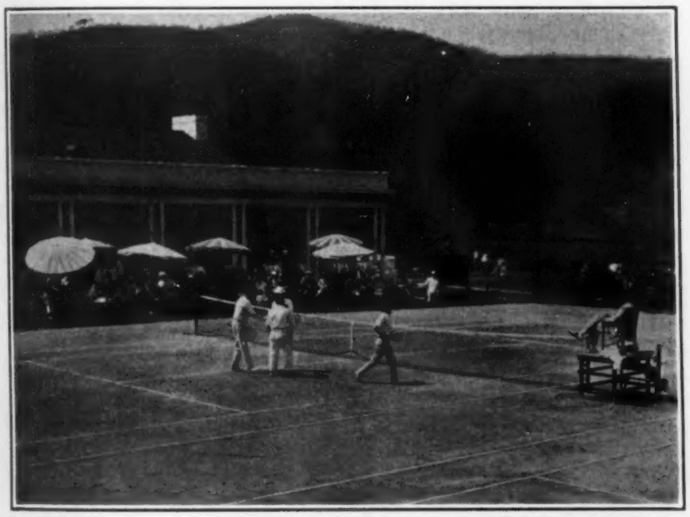
Eastern Trains

Lv. New York City	5:45 p.m.	Pennsylvania	Ar. 1:00 p.m.	25.37	30.68
Lv. Newark, N. J.	6:08 p.m.	Pennsylvania	Ar. 12:40 p.m.	24.90	30.10
Lv. Trenton	7:07 p.m.	Pennsylvania	Ar. 11:58 a.m.	22.31	26.98
Lv. West Philadelphia	7:53 p.m.	Pennsylvania	Ar. 11:12 a.m.	20.51	24.82
Lv. Wilmington, Del.	8:34 p.m.	Pennsylvania	Ar. 10:36 a.m.	19.07	23.10
Lv. Baltimore	10:00 p.m.	Pennsylvania	Ar. 9:00 a.m.	15.32	18.60
Lv. Washington	11:00 p.m.	Chesapeake & Ohio	Ar. 7:40 a.m.	13.16	16.00

The Western trains will arrive at White Sulphur Springs at 8:55 a.m., June 16, and will leave for the return trip at 8:00 p.m., June 19.

The Eastern trains will arrive at White Sulphur Springs at 7:00 a.m., June 16, and will leave for the return trip at 11:40 p.m., June 19.

Equipment will include sleeping cars containing berths, sections, compartments and drawing rooms and a la carte dining car service.



TENNIS IS POPULAR AT WHITE SULPHUR SPRINGS
Devotees of This Sport Will Find Numerous Courts Available at the Casino

acceleration, or rate of change of acceleration be measured? How are these factors related? What consideration should be given to the element of time? What fundamentals must an instrument satisfy? These are among the items that will be included in an address by R. W. Brown, who has delved deeply into the riding-qualities problem.

BRAKES

O. M. Burkhardt has made a careful study of the fundamentals of brake design. In a paper on this topic, he will call attention to facts both theoretical and practical. What causes squeaking, chattering and grabbing of brakes, and how may these characteristics be remedied? Mr. Burkhardt will present his views, and an opportunity will be afforded for adequate discussion.

The Development of a Modern Four-Wheel Mechanical Braking System will be described by J. R. Cautley and A. Y. Dodge. An elaborate demonstration will accompany this paper.

Engineering factors in the design and construction of hydraulic brakes will be included in the contribution of H. E. Maynard.

TRANSMISSIONS

What are the fundamental principles involved in the unconventional transmissions recently developed? What should be expected of a transmission? How are the requirements carried out in the numerous designs? P. M. Heldt will answer these questions and others at the Transmission Session. Opportunity will be afforded for the display and demonstration of new transmissions and gearshifts of the unconventional type.

What is the influence of tooth number ratio, alignment, tooth profile and other factors upon the noise produced by a

SOME OF THE COTTAGES AT WHITE SULPHUR SPRINGS
Cottage Life is a Feature at This Resort. This View Shows the Tavern and South Carolina Rows

given transmission? A recent investigation of the probable sources of transmission noise will be reported by Earle Buckingham.

Hotel Accommodations

At this time over 600 reservations have been received for accommodations at the Greenbrier Hotel and its cottages. It is expected that this number will be considerably swelled before June 16, and it is strongly recommended that all those who have not already applied do so at once. The equipment and facilities offered by the Greenbrier are unexcelled, and the cuisine is well-known throughout the Country. The golf courses, tennis courts, bridle paths, swimming pools and other facilities for sports and recreation are among the best, and all will be available for the enjoyment of our members.

Transportation

Reduced railroad fares have been granted by the various railroads throughout the Country for members of the Society and dependent members of their families.

Certificates entitling members to purchase round-trip tickets to White Sulphur Springs and return to the point of departure at one and one-half times the regular one-way fare will be mailed with the next *Meetings Bulletin* that should reach you about June 8. Those attending as guests of members will find it advantageous to buy Summer Tourist Tickets.

Special Accommodations

Arrangements have been made with the Big Four Lines and the Pennsylvania and the Chesapeake & Ohio Railroads for special accommodations for our members from principal points in the Middle West and the East to White Sulphur Springs and for the return trip.

Requests for your accommodations should be made to the railroad agent in your locality. Certificates will be made available as indicated above. Agents will be at the Greenbrier Hotel to make reservations for the return trip.

A schedule of trains and a table of fares is given on p. 559. This information is furnished merely for the convenience of members and with the understanding that the Society assumes no responsibility for any errors that may be contained therein. *It is recommended that all arrangements for transportation be made promptly upon receipt of the certificate, either through your local Section or directly with the railroad agent.*

Automobile Routes

In the preceding issue of The Journal, it was announced that information regarding preferred routes would be obtained from the American Automobile Association and published for the benefit of those who wish to drive to White Sulphur Springs. A description of routes was published in the *Meetings Bulletin* of May 21. Since that date, two corrections to the route description have been received, and the description is here reprinted with the corrections incorporated:

> From New York City south to White Sulphur Springs, two routes over good roads can be followed. The first route goes south over the Lincoln Highway from New York City through Newark, Elizabeth, New Brunswick, Princeton and Trenton, N. J.; Langhorne, Pa., and Philadelphia; thence through Overbrook, Coatesville, Lancaster, York, Gettysburg and Chambersburg, Pa.; then south through Hagerstown, Md., and down the famous historic Shenandoah Valley Pike to Staunton, Va. This route includes all hard-surface roads reported in good condition and free from detours of any consequence at the present writing.
>
> From Gettysburg, if your members desire they can eliminate Chambersburg and Hagerstown by going through Emmitsburg and Frederick, Md.; then west through Harpers Ferry and Charlestown, W. Va., and Berryville, Va., to Winchester, Va.; and then south along the Valley Pike through Woodstock, Mount Jackson, New Market and Harrisonburg to Staunton, Va. This is all good hard-surface road.
>
> The best route from Staunton to White Sulphur Springs goes via Churchville, Jennings Gap, Deerfield, Armstrong, Green Valley, Bath Alum Springs, Warm Springs, Hot Springs and Covington, Va., to White Sulphur Springs, W. Va. The road from Staunton to beyond Jennings Gap, Va., is improved, then unimproved to Warm Springs, improved to beyond Covington, and mostly dirt into White Sulphur Springs. The dirt sections in this vicinity are dependent upon weather conditions and would be fair when dry but poor after heavy rains. However, in the month of June when there is plenty of hot sun to dry out the roads, tourists should have little or no difficulty.
>
> The other route from New York City goes via Newark, Springfield, Plainfield, Bound Brook, Somerville, White House and Phillipsburg, N. J.; Easton, Allentown, Reading, Lancaster, York, Gettysburg and Chambersburg, Pa., and Hagerstown, Md.; then south over the route as previously outlined. This route includes all hard-surface road reported in generally good condition at the present time.
>
> The best route from Buffalo runs via Batavia, Avon, Mount Morris, Dansville, Bath, Painted Post and south through Erwins, N. Y.; Lawrenceville, Mansfield, Liberty and Williamsport, Pa.; east through Muncy; then south over the famous Susquehanna Trail through Sunbury, Liverpool and Harrisburg, Pa.; then west through Carlisle to Chambersburg, Pa.; and over the route as given above. The road on this route from Buffalo to Chambersburg is all hard-surface and reported in generally good condition.
>
> From Detroit two routes can be followed south to Toledo and then either (*a*) east via Fremont, Norwalk and Oberlin to Cleveland; thence via Chagrin Falls and Warren, Ohio; Sharon and Mercer, Pa.; south through Butler, Pa., to Pittsburgh and east over the Lincoln Highway through Greensburg, Ligonier and Bedford to Chambersburg, Pa.; and then south as outlined previously, or (*b*) south from Toledo through Bowling Green, Findlay, Carey and Marion, Ohio, to Columbus, then east over the National Old Trails Road through Zanesville, Ohio; Wheeling, W. Va.; Washington and Uniontown, Pa.; and Cumberland and Hagerstown, Md. Both of these routes include all good hard-surface road.
>
> For the route from Cleveland your members could pick up the course as outlined in the route from Detroit south to destination.
>
> Since the convention is not until the middle of June, we would advise your members to make inquiry along the route at our various clubs to get the latest information from point to point, as conditions change practically every week.

RIDING-COMFORT AND ALLIED PROBLEMS

Distinguished French Visitor Addresses Joint Meeting at Boston

Automobile Body Suspension and Riding-Comfort was the subject of a very interesting paper presented on the evening of May 21, at the Engineers Club, Boston, before a joint meeting of the Boston Section of the American Society of Mechanical Engineers and the Society's New England Section. The speaker on this occasion was Prof. Pierre Lemaire, assistant director of L'Ecole Centrale Lyonnaise, France, who is in this Country this year as the Third French Exchange Professor of Engineering and Applied Science, under terms of agreement between the French Government and American universities.

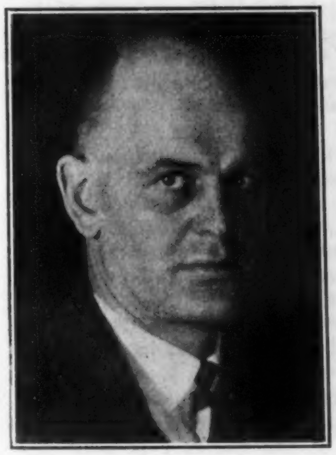
Prof. C. F. Park, of the Massachusetts Institute of Technology, who is a member of both participating societies, presided, and Professor Kennelly of Massachusetts Institute of Technology and Harvard University very kindly accepted an

invitation to be present and to act as interpreter for Professor Lemaire, should the need arise.

Professor Lemaire spoke of the results of his extensive researches into the problems of body suspension and passenger-car design and the problems associated with the constant improvement of riding-comfort. His paper showed that his work has been of a very technical, though highly productive, nature and that he has attacked the problem from both a purely mathematical and a practical standpoint. His remarks dealt with the results of his experiments as directly applicable to automobile design. The discussion that followed Professor Lemaire's address was most interesting and profitable, and the meeting closed with a hearty vote of thanks to the distinguished speaker.

STEAM COOLING OF ENGINES

Reduction of Piston-Friction Losses Engages Milwaukee Section



A. G. HERRESHOFF

F. M. YOUNG

Piston friction is much the largest item of mechanical loss in an engine and, although the percentage of the maximum brake horsepower may be small, it amounts to fully one-half the indicated horsepower at light loads. This friction loss can be reduced materially by keeping the cylinder-walls and oil-film at a high temperature and consequently keeping down the viscosity of the oil on the rubbing surfaces. How this result may be accomplished by steam cooling was described by Alexander Herreshoff at the monthly meeting of the Milwaukee Section on May 6. The various types of radiator core and the methods of constructing them were explained by F. M. Young, and highway safety was the subject of a discourse by President Horning.

By reducing piston friction and improving vaporization, said Mr. Herreshoff, the high temperature of the cylinder-walls at part load produces better economy, which, in practice, has been found to average 20 per cent more miles per gallon on several cars of different makes. The ideal temperatures arrived at by full-load tests on a dynamometer are not maintained in practice but vary with the design of the engine and with the quantity of heat that the intake charge receives from the jacket before entering the cylinder. Investigations have shown that if a fixed intake-temperature is maintained, the brake horsepower increases with the increase of temperature of the jacket up to 212 deg. fahr., or as far as the observations have been continued. Practically no dilution occurs if the jacket is maintained at 212 deg. fahr.

A by-product of steam cooling is the steam heater for the body. Obviously, with such a heater there is no odor, noise or fire hazard and the control of the heat by a small valve adds to the comfort of the passenger.

FACTORS OF CONSTRUCTION

Mr. Young outlined the more important factors that enter into good radiator and core construction, specified the proper mounting of the radiator, and explained the different types and their applicability for the work for which each may be chosen. Although equal in importance to other parts of the machine, the radiator, he said, is usually the last to be designed and must fit into whatever space is available after the layout of other parts has been determined.

Cores, he continued, are classified into the individual fin and tube, the continuous fin and tube, the ribbon cellular and the air tube cellular types. The fin and tube core, although largely used on both trucks and passenger cars, is now almost entirely confined to the heavier and larger trucks, in which bulk, weight and extreme dimensions can be realized without particular difficulty, such, for instance, as the Class B Liberty trucks. Among the advantages of the continuous fin and tube type are the possibility of replacing the lapped joints with mechanical seams, the unrestricted water-circulating channels, ease of manufacture and the general familiarity with it. Because of its simplicity, fast production is possible without the aid of skilled labor or intricate machinery. In some types the tubes are straight in line, in others they are staggered. Other details of manufacture also vary according to the ideas of the maker.

Ribbon cellular-type cores have excellent efficiency as heat dissipaters. Two kinds of spacer are used, one to disturb and baffle the air, the other to give metallic contact throughout the greater part of the core depth. When made with flat corrugated tubes having mechanically seamed joints, the water channel has a greater useful depth, fewer and stronger joints are obtained and the structural rigidity is increased. The greater structural strength renders them desirable in certain classes of chassis construction and their efficiency makes them desirable when only small frontal areas are available. The continual breaking-up of the water film in passing through the core takes a greater percentage of the heat from the water than does a straight core and the washing action from side to side also accomplishes this result. Its cost of manufacture is low.

The air tube cellular core, better known as the honeycomb type, produces a rigid structure and provides both a lateral and a vertical flow of water. It would be used more extensively if its cost of manufacture were not so great.

The type of core suitable for a particular class of work will depend upon the strain and vibration that it must withstand and the protection that will be provided by the outer structure. Climatic conditions also have their effect. In the industrial field, flexibility of the lighter types is giving way to strength, which enables the radiator to receive rougher handling, eliminates the necessity for expensive cast frame and tank construction and lends itself to more flexible and faster production through the use of stampings and sheet-metal parts. When assembled and soldered the radiator becomes practically an integral mass that cannot be made to leak by vibration or diagonal strains and is immune to damage from freezing.

BRONZE THE BEST MATERIAL

Brass, bronze and copper are the materials generally used for cores. Steel or iron inserts are sometimes used but are not considered good practice. Brass, although the least satisfactory because of its porosity, short life and the fact that such a core is easily ruptured, less ductile and can be worked less, is however extensively used in tubular radiators both for fins and tubes.

Because of its capacity to serve as a conductor and dissipater of heat, copper is used largely for fins and cross sheets on tubular cores, but is seldom used for cellular radiators because impurities in the water are liable to set up an electrolytic action, producing decomposition and causing leakage.

Bronze, being composed of approximately 85 per cent of copper and 15 per cent of zinc, is the best radiator core material, the copper furnishing ample ductility and the zinc the tensile-strength and rigidity. It has less porosity than brass and greater longevity in the lime and alkali districts than either brass or copper, unless they have been tinned completely.

Solder for cores usually ranges from 40 per cent of tin and 60 per cent of lead to 50 per cent of each, which grade is to be used being determined by the manufacturing problems that enter into it. The greater strength obtainable with the 50-50 mixture, however, causes it to be preferred, although it is more costly.

In general, radiators are divided into three classes: (*a*) the pressed shell type with removable core and tank assembly, (*b*) the cast tank type and (*c*) the integrally constructed sheet-metal tank type. The first mentioned type is used almost entirely for passenger cars, light trucks and taxicabs; the second in the heavier truck and industrial fields and the third with smaller units in industrial service, although for many years it has been used successfully with the heavier classes of work. It is seldom found in passenger cars.

Inasmuch as practically all the heat is taken from the core by convection, rather than by radiation, the relation of the size of the fan to the size of the radiator is very important.

CLUTCH-DESIGN CONSIDERATIONS

Detroit Section Hears Efficient Single-Plate and Two-Plate Types Discussed

Many important points of clutch design, such as friction facings, engagement methods, cooling and thermal efficiency, adjustment, methods of control, lubrication of release sleeves and balancing, were discussed by E. E. Wemp, engineer of the Long Mfg. Co., at the meeting of the Detroit Section which was held on May 21. He argued that, since the clutch virtually converts engine torque into heat during the period of slippage just previous to full engagement, and since the heat must be dissipated through the clutch mechanism, the thermal efficiency of the clutch is of great importance.

Severe service required of motorbuses has emphasized the importance of having a clutch rid itself of the large quantity of heat generated as a result of its frequent usage and, from his experience, Mr. Wemp concludes that:

(1) If careful consideration is given to the subject of thermal efficiency, the unit pressure of the facings is unimportant over a wide range of pressures

(2) As a result of conclusion (1), it is believed that a single-plate or a two-plate clutch is the logical design for heavy-duty service. This is largely because it is much easier to provide for the necessary masses of absorption metal in these clutches than in the multiple-disc type

(3) The masses of absorption metal should be carried as a part of the flywheel weight

(4) Cast iron is the best metal to use as a friction surface for engaging the facing. The free graphitic content of cast iron provides a slight lubricating effect and permits the surfaces to attain a smooth high polish

(5) With their present knowledge of the subject, the engineers of the Long Mfg. Co. attempt to provide two elements for increasing the thermal efficiency of the clutch. A considerable mass of metal is provided in the driving discs, and this mass is designed to provide a large exposed area for a surface radiation. The mass serves as a reservoir that absorbs a large number of heat units without raising the temperature of the driving disc too quickly

For the single-plate type, the flywheel itself constitutes a driving disc that absorbs directly 50 per cent of the heat liberated, and 25 per cent of the liberated heat is absorbed directly in the two-plate type. Non-adjustable forms of clutch are practicable for engines developing not more than 2000 lb-in. of torque. Beyond this capacity, either the driven-disc diameter must be so large as to handicap shifting or the pedal pressure must be excessive.

Mr. Wemp believes that the use of the single-plate clutch will increase and that this will be accompanied by improvements in present designs to effect better operation and to provide increased durability; that a single-plate clutch may be perfected which obviates the necessity of a sliding spline fit between the clutch-hub and the driven shaft; and that some simple means will be developed for damping vibration between the engine and the driving system, and that self-lubricating clutch throw-out bearings will be perfected.

CORRECT ENGINE LUBRICATION

San Francisco Group Told How Oils Must Be Selected and Used To Avoid Trouble

Three inseparable essentials for prevention of engine lubrication troubles are (*a*) an oil of the highest quality, (*b*) an oil of correct body and character to meet the requirements of the particular engine and (*c*) proper use of the oil, members of the San Francisco group were told at a meeting on May 28 by H. L. Dickey, engineer of the manufacturers' service division of the Vacuum Oil Co., in an address that covered the subject of engine lubrication in a comprehensive, simple and instructive way.

Wide variation in crude petroleums is found aside from the difference in quality of paraffin and asphalt or naphthene base oils, he said, but as the asphalt is always removed in refining, an oil made from either of these classes does not necessarily possess unusual characteristics; very fine oils are made from both types and inferior products may be made from either. Flash, fire, viscosity and gravity tests are unreliable guides to the quality of an oil, as it it possible to make up two oils to the same specifications, one of which will be a high-grade product and the other entirely unsuited for automobile engine lubrication.

The important point is to select the grade of refined oil that will maintain a film of just the right thickness, at the temperature at which an engine operates in normal service, to protect the working surfaces and prevent blow-by yet not be unnecessarily viscous. If the operating temperature is relatively high, a heavy rich oil is desirable, but a lighter-bodied oil of the proper character will protect an engine that operates at a moderate temperature. Splash lubrication handles the lighter oils effectively but the force-feed system is better for heavy oils. A slow-speed engine requires a heavy oil to provide a seal between the cylinder-walls and the pistons but a light oil is just as effective in a high-speed engine.

Viscosity is a measure of the resistance to motion of the bearing parts, said Mr. Dickey, and as the engine speed increases, the resistance increases proportionally and represents an important power loss, hence the use of too heavy an oil causes unnecessary fuel waste.

Selection of the proper oil also has an important bearing on detonation knocks, as the formation of carbon deposits due to oil-pumping tends to increase the combustion-chamber temperature, whereas the prevention of oil-pumping aids in preserving high compression and, consequently, fuel economy. Idling of the engine increases carbon formation, as the heat is insufficient to burn the oil that passes above the piston-rings. Oil must be very clean-burning or control of the oil supply must be very effective to give satisfactory results in an engine that is very sensitive to carbon deposits. Great care should be exercised to keep the oil clean; the crankcase should be drained frequently but not washed out with kerosene, and the reservoir should be kept full but not over-filled.

When an engine has become worn, it is not advisable to use a heavier grade of oil than was originally necessary; this only invites trouble from imperfect oil distribution and carbon formation. The proper remedy is to have the worn parts replaced. To get the best results, the cylinders should be refinished and fitted with oversize pistons that have been properly balanced.

Rust or corrosion of the bright parts is caused by water or by sulphur compounds resulting from the use of improperly refined benzol in the fuel. The water is due to condensation of the water vapor of combustion when the engine is operated at too low a temperature. With a force-feed engine, as the bearings wear, the oil flows faster and the pressure drops. Instead of adjusting the by-pass to increase the pressure, the speaker said, the proper procedure is to adjust the by-pass for a lower pressure so that more oil will flow through it and less through the bearings, thereby avoiding over-lubrication.

SOUTHERN CALIFORNIA SECTION FORMED

Los Angeles Group Formally Made a Section at Well-Attended Meeting

WATT L. MORELAND

Members of the Society composing the Los Angeles group, who have been very active and held regular monthly meetings for some time past, at which interesting and instructive papers have been delivered, were declared formally established as the Southern California Section by H. L. Horning at a meeting that was held in Los Angeles on May 22.

One hundred sixty members and guests were in attendance and were addressed by a number of distinguished men in addition to President Horning, of the Society, who was the principal speaker of the occasion. Others who spoke were Boyle Workman, acting mayor of Los Angeles; David Faries, representing the Automobile Club of Southern California; Don Smith, vice-president of the Los Angeles Motor Car Dealers' Association; William Fairbanks, president of the Automotive Council; R. S. Craig, president of the Service Managers' Association; Fred Wagner, representing the automotive editors of the daily newspapers; Lloyd Aldrich, secretary of the Los Angeles Section of the American Society of Civil Engineers; and H. H. Crites, automotive engineer, representing the Los Angeles Chamber of Commerce.

The chairman of the meeting was Ethelbert Favary, consulting engineer of the Moreland Motor Truck Co., who, at the close of the meeting, telegraphed the New York City office of the Society as follows:

> Members send Society headquarters greetings and are grateful for sanctioning Section here and give assurance of cooperation to make Southern California Section an important member of parent Society. We are sending President Horning back but with distinct understanding that he return soon to give us another talk.

President Horning spoke mainly on lubrication, in his usual humorous and pleasing way, but added some remarks having particular reference to the automotive situation in California. The investment in automotive equipment in that State is four times as much per inhabitant as in any other State or country; the State absorbs half as many automobiles as are exported from the United States; Californians travel farther per year than the residents of other States and countries, and the six-wheel trucks and motor-coaches and the gasoline-electric motor-coaches developed in the State mark a great advance.

Speaking of other developments, he said that great efforts are being made in engineering to promote highway safety, that the problem of headlighting is about to be solved, that balloon tires are a great economic advance and that four-wheel brakes, while not a necessity, add to the pleasure of driving.

On the main subject of lubrication he offered the bon mot, "if an engine wears-in quickly it wears-out quickly." A clearance of from 0.002 to 0.003 in. is needed between bearing surfaces to let the oil get in, he said. The top piston-ring violates the laws of lubrication and at least 80 per cent of the heat accumulated by the piston goes out through this ring and the oil-film to the cylinder-wall. Detonation, which is induced by high localized temperatures, is less severe, he said, when the engine is steam-cooled, because the temperatures are more uniform; if the cylinders are kept at the temperature of steam, dilution of the lubricating oil will be prevented; moreover, if steam-cooling is adopted, the radiating surface can be reduced one-half. He also spoke of the great advances in refining methods made by the petroleum industry.

INSTALLATION OF OFFICERS

The officers selected to guide the new Section through its first year are as follows:

Watt L. Moreland	Chairman
F. D. Howell	Vice-Chairman
Ethelbert Favary	Secretary
J. Jerome Canavan	Treasurer

MECHANICAL CAR-APPRAISAL TESTING

Detroit Section Learns How Degree of Overall Car Performance Is Ascertained

R. B. WASSON

Believing that most motor vehicles are really much more efficient than the general public believes them to be and that general abuse and neglect are usually the causes of owner dissatisfaction, an effort was made by R. B. Wasson, of the T. N. T. Engineering Co., Newark, N. J., to provide mechanical means to determine faults and to improve conventional methods of servicing and maintaining motor vehicles. His paper on Appraising Cars by Comparison of Mechanical Efficiency, which was read at the May 7 meeting of the Detroit Section, described the apparatus used, the methods employed and the results obtained.

Measurement of the degree of overall performance of a car, by devising and utilizing suitable apparatus and instruments, constitutes the plan, "overall" performance being understood to mean the ability of a car to transport persons or commodities and the character of its performance as represented by the degree of certainty, safety, rapidity and economy with which it operates, compared with what it was designed to do and what can reasonably be expected of it. The performance is studied in its relation to established standards and tolerances. When the performance of any essential factor falls below the tolerances, the detection apparatus, tests and comparisons, with their individual tolerances considered, make it possible to determine the causes quickly and accurately. The assumption is made that car performance, as measured by power developed, fuel consumed and all round ability, is controlled by various contributing factors and that, if the performance of each of these is satisfactory, the overall performance must be satisfactory. The tests are made more or less simultaneously and include:

(1) Horsepower delivered at the rear wheels, for any speed and for any load-factor

(2) Fuel consumption, for any speed and for any load-factor
(3) Leakage or slippage past the piston-rings during the compression and the working strokes
(4) Back pressure in the exhaust system
(5) Correctness of mixture, or fuel-air ratio
(6) Compression and working pressure in each cylinder
(7) Indication of oil-pumping
(8) Dilution and rate of dilution of the oil in the crankcase
(9) Leaking or sticking valves
(10) Temperature of the cooling water and of the lubricating oil

For testing, the car is driven up the ramps of the apparatus and forward until the rear wheels are in position on the driven supporting pulleys. It is prevented from moving forward or backward by an adjustable clamping member fastened securely to the front axle, and this triangulates the thrust so that little or no side creeping of the rear wheels can occur. Rear holding clamps also obviate any sidewise motion, or accident in case a rear tire blows out. Slippage of the rear wheels under a heavy power load is counteracted by turnbuckle adjustments.

Other means are also provided for testing the operation of the car, including a prony brake for absorbing the power, water cooling and the like. The testing instruments are grouped on or near the main apparatus framework. They include a torque meter, a tachometer, a flow meter to measure fuel consumption, a gasometer to determine the amount of slippage past the piston-rings and other devices. The correctness of the mixture is checked by determining the percentage of carbon dioxide contained in the exhaust gases, and the compression of each cylinder is ascertained by using an impulse pressure-meter. Details of the procedure for the entire set of testing operations were illustrated and explained.

AUTOMOBILE HEADLIGHTING PRINCIPLES

Discussion of Essentials Enlivens Meeting of Metropolitan Section

What are the requirements of effective and satisfactory head-lamp illumination? Do they comprise a glare under control for intensively lighting the highway ahead or diffused lighting that will spread itself over surrounding objects as well as the highway? What are the effects of deflection of the springs, of variations of contour of the road, and of narrow crowned roads, in throwing piercing rays into the eyes of an oncoming driver? Presenting a paper entitled Fundamental Principles of Automobile Headlighting, before the monthly meeting of the Metropolitan Section at the Hotel Majestic, New York City, on May 21, H. M. Crane touched on these and other topics and stirred up an animated discussion that lasted long after the customary closing hour.

First quoting from the report of the Committee on Motor Vehicles to the National Conference on Street and Highway Safety, Mr. Crane stated that the object of his paper was to explain the difficulties that have arisen in the operation of the system of head-lamp regulations sponsored by the Society working in conjunction with the Illuminating Engineering Society, and to suggest a possible line of fundamental research intended to allow the drafting of more desirable regulations.

The first really serious objection to head-lamp glare, he said, came as a result of electric lighting, largely because the car manufacturers and the lamp makers working together produced an extremely powerful beam in a highly concentrated form. New Jersey was the first State to accept certain devices for use and these were based on the personal examination of the controlling officer.

Control of Head-Lamp Beam

One of the first solutions proposed by the Society was based on the control of a concentrated head-lamp beam, the rays of which were sufficiently far below the horizontal to prevent their reaching the eyes of the driver of an approaching car. This produced an excessive illumination within a limited area and practically no illumination elsewhere. The next step was to provide a complete driving-light as well as to keep the glare under control. This work resulted in the formulation of the regulations listed on p. B7 and subsequent pages of the S.A.E. Handbook.

This type of regulation is effective, however, only on a perfectly level surface and the desired control can be upset by slight variations in the contour of the road and by small errors in adjustment. Enforcement of the regulations is difficult because of the number of automobiles in service and the fact that they may get out of adjustment within a day after they have been checked, on account of changes in the equipment, the burning out and replacing of bulbs or some change in the loading of the vehicle.

Further, tilting produces excessive illumination of the roadway directly in front of the vehicle and renders the driver oblivious to objects beyond. At point *B* in the S.A.E. Handbook diagram a minimum of 7200 cp. is required. Many companies claim several times this amount. In a car having a 113-in. wheelbase, a deflection of 2 in. in either the front or the rear springs causes a shift corresponding exactly to 1 deg. of the head-lamp beam. The same result is produced by a change in the contour of the road. On narrow crowned roads even the act of turning out to pass results in a lateral tilting that is sufficient to direct rays 1.5 deg. from the horizontal into the driver's vision at close range.

Intensity of Illumination

The question is, continued Mr. Crane, whether any advantage accrues in having more light directed on the road surface a short distance in front of the car than is necessary to pick out minor road obstructions and similar obstacles. Regarding further research, he declared that he is strongly in favor of a study of the ability to see under a wide variety of light distribution, and that he does not believe that the judgment of a man behind the head-lamp can be depended upon to determine its efficiency. An average driver is too prone to judge by the brightest part of the field of illumination and not from the all-round completeness of the lighting. Research, he thought, should also cover the kinds of lighting required in different parts of the Country on different types of road and with different densities of traffic.

In conclusion, Mr. Crane believed that maximum values must be placed on the supposedly non-glaring beams, that is, those below the horizontal, and that this maximum value should be low enough to justify the use of diffused lighting on vehicles of moderate speed, including a great majority of the passenger cars which, because of their low price, inferior equipment and deficient up-keep are the greatest offenders.

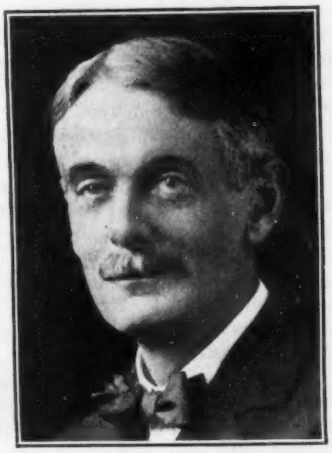
Symmetrical mounting of lights he believed to be desirable merely for reasons of appearance, spot-lights and "courtesy" lights, even though crude, having shown the possibilities of asymmetrical illumination. The suggestion was made that in congested traffic a single head-light might be used on the right side and that on the left side be replaced with a marker or with a lamp of moderate power throwing a diffused light, or vice-versa.

The use of the "courtesy" light in conjunction with dimmed head-lamps, Mr. Crane believed, would be a material improvement over the present system.

Suggested Changes in Mounting of Lamps

In opening the discussion, T. H. Pratt compared the effect of present head-lamp illumination to that of driving through a tunnel and suggested that better lighting of the roadway might be obtained by mounting the lights in some other manner or place, as, for instance, on top of the car or underneath the front axle. He called attention to the fact that,

J. H. Hunt



H. M. Crane

as it frequently takes 2 sec. for the eye to adjust itself to differences in intensity of illumination, the driver of a car traveling at the rate of 30 m.p.h. sometimes covers 88 ft. while practically blind.

J. H. Hunt, by means of charts, showed the changes in the angle of deflection before and after cars of different makes were loaded to capacity. He found that the lights of his car had been tilted too high and that better results were obtained when the lights were tilted down 1 deg. when the car is fully loaded. He questioned the need of so great candlepower and cited the possibility of finding one's way home on a pitch-dark night in the country by the aid of the light from frequent flashes of lightning. Other charts showed distribution curves with frosted bulbs and the results of tests made with the discs used by the Royal Automobile Club of Great Britain.

W. T. Fishleigh agreed with Mr. Crane that the present system is not perfect, that difficulty has been found in enforcing the laws in different states, and that much remains to be done. He believed that a maximum should be placed on the points of side illumination. In his opinion, the two problems of head-lighting consist of (*a*) having plenty of road light with a distribution not only down the road, but to the side, and some in front of the car, and (*b*) watching the approaching car and not being put off the road by its glare. He believed in "sticking to" the present system in spite of its defects.

Enforcement Is Necessary

The present regulations are good, but the enforcement of them is bad, in the opinion of T. J. Lítle, Jr.

J. J. Shanley, of the State Motor Vehicle Department of New Jersey, welcomed any specifications adopted by the Society. His department, he said, is equipped to make drives in an intensive way but its efforts are not supported by the manufacturers, who continue to send out cars by the thousands on which little or nothing has been done in the way of focusing the head-lamps.

Dr. C. H. Sharp called attention to the fact that the head-lighting problem is a compromise between the glare that other drivers can reasonably be asked to endure and the illumination that the driver of the car carrying the head-lamps must have. Its deficiencies have been mentioned but nothing has been said of the counterbalancing advantages of the present system. Conditions would be intolerable without some reasonable set of regulations. In the regulating system, an effort is made to throw the light where it is wanted and to keep it away from where it is not wanted; in the diffusing system, it is smeared all over the landscape, whether wanted or not.

Light Controlled by Driver

R. N. Falge believed that the present deficiencies are not inherent in the Illuminating Engineering Society's system of beam specification but that the specification had not yet brought about ideal practice. Progress, however, is being made. The prevailing opinion appears to be that means should be provided under the control of the driver for depressing the beam through a small angle, but considerations of cost and of mechanical difficulties have limited the application of this principle. Since this effect has been made possible most simply and inexpensively by merely switching from one filament to another that is slightly offset in the same bulb, large-scale application has become commercially attractive.

W. A. Ryan, expressing the opinion that diffused light is not the solution of the problem, that it is too glaring and too dangerous in a fog and that the trouble is not with present specifications but with the devices that they are supposed to cover, outlined specifications for a first-class head-lamp.

J. F. Howarth of Australia; R. E. Carlson and E. C. Crittenden, of the Bureau of Standards; O. M. Burkhardt, of the Research Department; A. W. Kellemeyer, of the New York State Bureau of Motor Vehicles, and W. W. Mathews, of the Pennsylvania Department of Public Highways, also took part in the discussion.

SECTIONS OFFICERS ELECTED

Results of Balloting for Leaders of Local Organizations for Coming Year

Officers who have been chosen by the Society's 12 active Sections to manage the affairs of their respective Sections during 1925-1926 are the following:

BUFFALO SECTION

L. H. Pomeroy	Chairman
J. W. White	Vice-Chairman
H. T. Youngren	Secretary
P. B. Jackson	Treasurer

CHICAGO SECTION

Walter J. Buettner	Chairman
F. C. Mock	Vice-Chairman
F. G. Whittington	Secretary
J. W. Tierney	Treasurer

CLEVELAND SECTION

John H. Jaschka	Chairman
Clyde S. Pelton	Vice-Chairman
L. L. Williams	Secretary
E. M. Schultheis	Treasurer

DAYTON SECTION

O. T. Kreusser	Chairman
H. W. Asire	Vice-Chairman
L. G. Meister	Secretary
Robert Insley	Treasurer

DETROIT SECTION

W. R. Strickland	Chairman
L. M. Woolson	Vice-Chairman
R. M. Anderson	Secretary
E. V. Rippingille	Treasurer

INDIANA SECTION

George T. Briggs	Chairman
F. F. Chandler	Vice-Chairman
Raymond Buckley	Secretary
Charles A. Trask	Treasurer

METROPOLITAN SECTION

Neil MacCoull	Chairman
A. F. Masury	Vice-Chairman
F. K. Glynn	Secretary
S. H. Woods	Treasurer

MILWAUKEE SECTION

J. B. Armitage	Chairman
G. W. Smith	Vice-Chairman
A. C. Wollensak	Secretary
Fred M. Young	Treasurer

NEW ENGLAND SECTION

Merl R. Wolfard	Chairman
E. P. Warner	Vice-Chairman (Boston)
Maurice Olley	Vice-Chairman (Springfield)
E. H. Lockwood	Vice-Chairman (New Haven)
W. Laurence LePage	Secretary
E. O. Wheeler	Treasurer

PENNSYLVANIA SECTION

Charles O. Guernsey	Chairman
R. W. A. Brewer	Vice-Chairman
Adolph Gelpke	Secretary
Ellis W. Templin	Treasurer

SOUTHERN CALIFORNIA SECTION

Watt L. Moreland	Chairman
F. D. Howell	Vice-Chairman
Ethelbert Favary	Secretary
J. Jerome Canavan	Treasurer

WASHINGTON SECTION

S. W. Sparrow	Chairman
Paul Lum	Vice-Chairman
Robert F. Kohr	Secretary
Conrad H. Young	Treasurer

ADVANTAGES OF HYDRAULIC STEERING

Better Car Control and Prevention of Shimmying Explained to Buffalo Section

J. W. White

The better performance of a car equipped with hydraulic steering-control was shown at the May 19 meeting of the Buffalo Section in a 5-min. motion-picture reel in connection with an address by J. W. White, chief engineer of the disc wheel division of the Wire Wheel Corporation of America. A number of lantern slides were also exhibited to show the mechanism by which the hydraulic control is effected. The object of the speaker, however, was to show the results in car performance that can be obtained by hydraulic steering and not to dwell upon the means used, since these are in the experimental stage, he said, and it is very probable that better means may be developed later.

Performance of the car, even with this experimental control, exceeded expectations and Mr. White believes that hydraulic steering-control will absolutely prevent shimmying, reduce tramping more than 50 per cent, cut down the steering effort and eliminate "wheel fight."

The hydraulic system possesses the dashpot or hydraulic-check effect that various investigators have found will stop shimmying and it eliminates backlash by dispensing with the drag-link. The system is partially reversible, like the usual steering mechanism, but this effect is damped by the dashpot effect of the liquid in the connecting pipes that serve as a by-pass, so that wheel shocks are eliminated. A Marmon car fitted with the system could be driven unbelievable distances, the speaker said, without the hand on the steering wheel and could be driven over curbs without manual control and without the marks of any of the tires on the pavement showing any deviation from a true rolling course. It was impossible for an observer to discern any front-wheel wabble on the roughest roads as the car approached. The tendency to tramp was much reduced and the radiator movement was noticeably diminished. There was a sense of stability at the front end of the car which was comparable with that at the rear end; no vibration from the road was felt at the steering wheel and yet the front wheels would come out of a turn with the slightest pressure on the steering wheel.

The system, as applied to the car, comprises a stationary double-ended piston-rod supported in brackets bolted to the center of the front axle, a movable hydraulic cylinder mounted on this rod, a divided cross-tie-rod from the steering knuckle-arms fastened at their inner ends to the exterior of the cylinder, flexible tubes from the ends of the hollow piston-rod to oil leads on the frame, connections to an oil-pump on the steering column and an oil supply-tank located on the dash, which may be the same tank as is used with the conventional hydraulic brake system.

The oil-pump at the foot of the steering column has an outlet to each end of the piston-rod on the front axle so that, as the steering wheel is turned in one direction, more oil is forced into one end of the hydraulic cylinder and causes it to move laterally, carrying with it the divided tie-rod and consequently turning both front wheels. Any minute leakage of oil is replaced automatically from the supply-tank.

Elimination of the drag-link is an advantage in the matter of prevention of shimmy because the drag-link, being positively located at one end on the car frame and attached at the other end to the steering-knuckle arm, tends to cause the front wheels to oscillate as the axle shifts forward and backward under the action of the suspension springs. Moreover, the use of the hydraulic control dispenses with most of the mechanical joints between the front wheels and the steering wheel, which joints must have freedom of motion and which wear, permitting wabbling motions of the front wheels to be amplified through the backlash.

The divided tie-rod permits better steering-system geometry, which also improves the steering control. According to the speaker, the steering-arm angles are practically 22 deg., or double the angle of the conventional construction, which is an advantage as regards clearances with front-wheel brakes. The geometry of the hydraulic system is much nearer theoretical correctness, he said, than the mechanical system, being perfect at a 40-deg. turning angle and 50 per cent better than the conventional system at 20 deg.

In the discussion following delivery of the paper, J. F. Palmer, consulting engineer of the Hewitt Rubber Co., said that he had attacked the problem of front-wheel shimmy in the last year from the tire standpoint and had come to the conclusion, as the result of numerous experiments, that the amplitude of vibration of the tires synchronizes with that of the springs and causes the phenomenon of shimmy. The amplitude can be governed in tires by altering the cross-section to an ellipse whose major axis is parallel with the axis of the wheel. This increases the carrying capacity of the tire by increasing the area of contact with the road, and he said he had demonstrated conclusively that a tire made on that plan would steer easier and eliminate low-speed shimmying and tramping.

Answering questions by P. B. Jackson, of the engineering department of the Pierce-Arrow Motor Car Co., Mr. White said that a ratio of 2½ turns of the steering wheel for full front-wheel travel is used in the gear oil-pump at the end of the steering column. The gear pump is reversible but not to the same extent as the average worm gear. The irreversibility increases inversely as the width of the gear face is reduced. This is one reason why a plunger pump in the lower end of the steering column is preferred to the gear pump, the plunger piston being operated by a rapid thread and nut, which gives the same condition as a worm plus the dashpot effect of the hydraulic system and damps out small impulses more effectually than the conventional steering gear. To have approximately uniform viscosity of the liquid used in the system, a solution of 50 per cent castor oil and 50 per cent alcohol is used in summer and 66 per cent oil and 33 per cent alcohol in winter. The latter proportion gives about the same density as a 50-50 solution would in winter in hydraulic brakes. Mr. White said that he believed the torque of the engine had much to do with shimmy, as

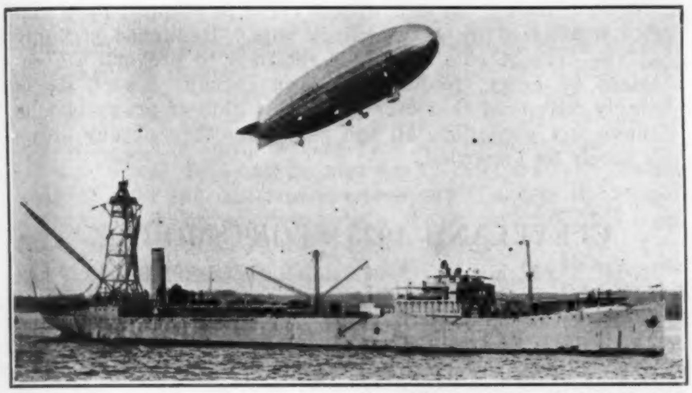
he had found that, at a speed of 53 m.p.h., the wheels shimmied with the power on but did not with it off.

A member observed that a great thing had been done in eliminating the drag-link, as he believed most of the trouble was caused by it. Replying, Mr. White said he thought it possible to go even further and eliminate the springs in the ends of the tie-rods.

AUTOMOTIVE ENGINEERS VISIT AIRSHIPS

Pennsylvania and Metropolitan Sections' Members Board the Los Angeles

A visit to the Lakehurst air station of the Navy and an inspection of the Zeppelin-built airships Los Angeles and Shenandoah, on May 12, took the place of the regular monthly meeting of the Pennsylvania Section. About 35 members and their guests motored from Philadelphia, arriving at Lakehurst at 2 p. m., where they were joined by about 50 members of the Metropolitan Section from New York City and vicinity.



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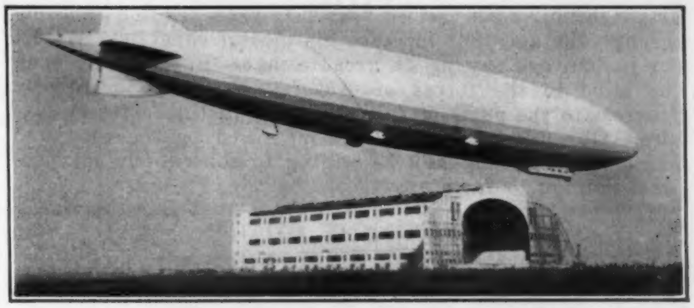
THE SHENANDOAH IN FLIGHT WITH ITS TENDER, THE U. S. S. PATOKA, IN THE FOREGROUND

The Use of a Vessel with a Mooring Mast, To Which an Airship Can Attach Itself and Receive Supplies, Greatly Increases Its Radius

Under the guidance of naval officers assigned to the Lakehurst station, a most interesting afternoon was spent in examining the great aircraft and hangars and gathering information about the design, construction and operation of the ships. Various members boarded the Los Angeles, which was being prepared for a cruise on the 15th. No prepared address was delivered, as it was thought the visitors would derive more enjoyment and benefit from being conducted about in small groups by officers, who made explanations in response to inquiries.



THE LOS ANGELES FLYING OVER THE HANGAR AT LAKEHURST, N. J.

SILVER-JUBILEE DINNER A KNOCKOUT

Remarkably Fine Addresses Enthusiastically Received at Indiana Section Function

The Indiana Section, George T. Briggs, chairman, certainly scored a big hit with the Silver Anniversary Welcoming Dinner it held, in conjunction with the Indianapolis Chamber of Commerce, at the Indianapolis Athletic Club. on May 29, the eve of the Thirteenth Annual International Sweepstakes. The dinner, like the 500-mile automobile race, was a record-breaker.

F. E. Moskovics, toastmaster, contributed greatly to the success of the occasion. In addition to the distinguished speakers, a large number of men prominent in the automotive world were guests, among these being Past-President Howard C. Marmon, General J. W. Joyes, W. G. Wall, F. F. Chandler, C. A. Musselman, Past-President Vincent, E. V. Rickenbacker and C. C. Hanch. President Fishback, of the Indianapolis Chamber of Commerce, was present. About 600 attended the dinner.

TRIBUTE TO THE ENGINEER

The dinner was a tribute to the accomplishments of the automotive engineer. C. F. Kettering, past-president of the Society and president of the General Motors Research Corporation, was the first speaker. He urged that all engineering work be based only on decisions made after adequate study. The natural impulse of human nature is apt to get in ahead of intelligence. Engineering is only finding facts about materials. Science is information about things. The various materials always react in the same way. It is the task of the engineer to learn what these reactions are, and to apply them. The educated engineer bows to them. The

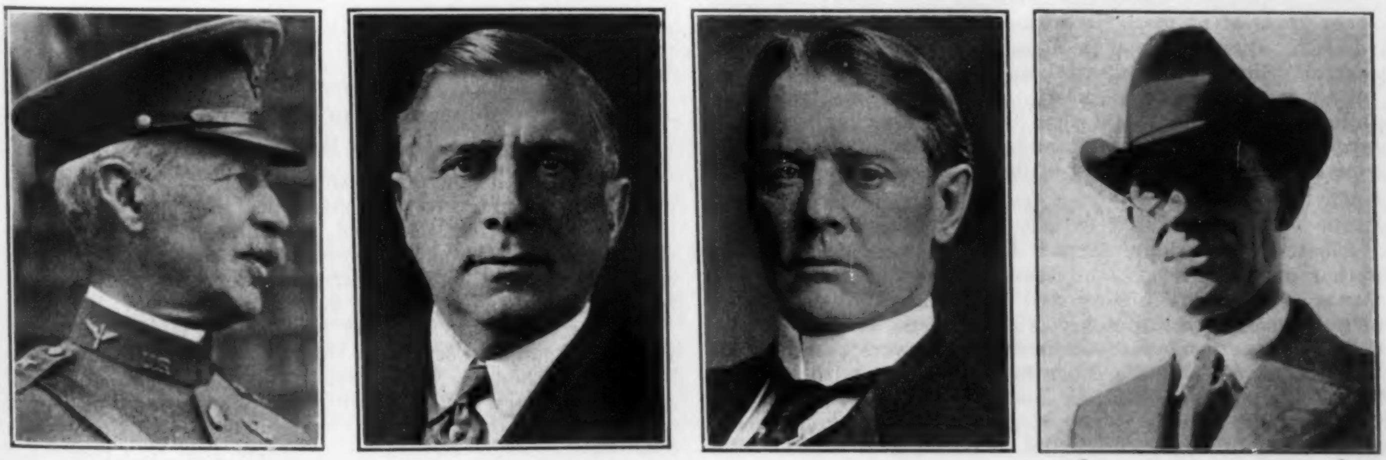


Photo. by Underwood & Underwood. Major-Gen. Mason M. Patrick | Copyright by Underwood & Underwood Charles M. Schwab | Albert J. Beveridge | C. F. Kettering

THE FOUR SPEAKERS AT THE DINNER IN INDIANAPOLIS ON MAY 29

first lightning-flash carried "static." Man has done nothing through the ages but increase his mental capacity. We let our human ego say we do great things. But we only open our mind to the forces of Nature. Man can eventually progress to the point of full utilization of the forces of Nature. Our development will be measured by the extent to which the engineer shall be willing to subordinate his personal opinion to facts.

The Realm of Aviation

In introducing Major-Gen. Mason M. Patrick, chief of the Air Service of the United States Army, Toastmaster Moskovics said that one of the purposes of the dinner was to do homage to aeronautics as an industry.

General Patrick referred very graciously to the work of many members of the Society in the field of aeronautics. He discussed in a clear forceful manner features of air transportation of mail, express and passengers, making the point that this has intimate relation to the problem of National defence. Under the conditions that are bound to prevail in this Country, it is vitally necessary that trained civilian pilots shall be available for Government service in emergency.

In General Patrick's opinion, our supremacy in the markets of the world is involved in our development and utilization of aircraft. Transportation, General Patrick said, is a ladder that man has climbed rung-by-rung from savagery to civilization. This Country used to be 100 days broad. The railroads shrunk that to a few days. Airplanes will bring it down to 20 hr. This is an augury of what is to come.

Every great innovation encounters opposition in the form of arguments, first, that it is impossible, secondly, that it is impracticable, and, thirdly, that it is uneconomical. In the case of aircraft, it merely remains to be demonstrated that they are economical. The value of time in general must be made clear. General Patrick believes that this problem will be solved quickly. Applying to aviation the same intelligence and daring that made the automobile, the future of aviation in this Country will be assured.

At the conclusion of General Patrick's address, Bill Herschell, the Indianapolis poet, recited some of his very entertaining stanzas.

Business and Optimism

Charles M. Schwab gave one of his inimitable talks. More important than technical learning, he said, is "human engineering." He defined the latter as the work of so directing the abilities of human beings that they achieve great results. The happiest time is when all work as a unit, because the human engineering has been well done. That indicates the nature of the real problem that confronts the Country.

Mr. Schwab said that today is the time of all others to start a career; great as have been the past developments, they will be excelled. It is good that we are a "material" nation, with great automobile factories, steel works and many other kinds of plants. No business devoid of sentiment will succeed. Business done in a happy frame of mind is successful. Sincerity is essential, as are courage and optimism. In advocating repeated effort, notwithstanding temporary failure, Mr. Schwab said that he had never built a plant large enough to meet the demands of the Country. The happiness of business is the joy of duty well performed.

The Age of Science

Albert J. Beveridge, former United States Senator and author of the Life of John Marshall, reviewed various climaxes of epochs of history and vital phases of the science of government. His speech was a great one, very effectively delivered. Certain observations he made were to the effect that the miracles of the Bible do not compare with radio so far as the mystery of them is concerned; mere locomotion without good purpose is not of great value; and, inasmuch as all things reach their climax, it is doubtful whether the world will ever see anything that will compare with the achieving of the greatest implement of the age, the automobile.

This age will be known as the age of science. Obviously, it is not absorbed in matters of government. The Greeks reached the climax in sculpture and philosophy. We are still trying to match the work of Phidias. Rome inducted the age of administration. She builded so well that in her decline she did not fall for several hundreds of years. The roads she built are still the chief highways of Europe. Later came the age of architecture and color. The Cathedral of Chatres cannot be duplicated. We cannot begin to imitate, let alone duplicate, the best of the product of the stained-glass art of former days.

Then, dealing with human beings, the founders of the constitution of this Country established a new epoch, in government. Our Government, unlike all others, is based on the sober second-thought of the people. Lincoln said, "The people always wabble, but they wabble right in the end." The sober second-thought of this Country is, Mr. Beveridge said, the Senate of the United States. He felt that it would be the gravest of errors to change the rules of the Senate, as has been proposed, so that debate could be stopped by a majority instead of by a two-thirds vote. He urged strongly that the present rule should be retained to prevent the enactment of hasty, foolish and even corrupt laws. He is strongly convinced that otherwise the rights of property and, without any exception, all the most cherished of our ideals will surely be imperiled.

CLEVELAND 1925 SPORTSMOBILE

Model X of this joyful vehicle, the design of which has been in process for several moons, was approved and put into production on May 23, when, according to advices from the Cleveland Section, its third annual sports meeting and picnic was run over the test course. Data regarding the details of its performance indicate that the speed was well over 100 m.p.h. before the speedometer broke, that no dilution occurred until a storm necessitated shelter, that then the acceleration was spontaneous and that, at the luncheon, the pick-up was rapid and the fuel consumption enormous.

So, Saturday, May 23, was Cleveland's great family day, the day when all the folks, big and little, can demonstrate how well they know how to play. In spite of indications of bad weather, more than 100 members and guests, including many ladies and children, gathered at the grounds of the Nela Park Works of the General Electric Co., provided through its courtesy and the agency of R. N. Falge, and the fine assembly hall became a welcome substitute for all outdoors when a storm put a Lanchester damper on the field and track events.

L. L. Williams, of the Cleveland Automobile Co., acted as chief starter of the events; William H. Miller, president of the International Metal Hose Co., acted as judge; and Edge Austin, of the Timken Roller Bearing Co., was general master of ceremonies.

INSPECTION OF McCOOK FIELD

Airplane Development Work and Exhibition Flights Seen by Dayton Section Members

Members of the Dayton Section participated with members of the American Society of Mechanical Engineers in an inspection visit to McCook Field, Dayton, Ohio, on May 16 to observe some of the more important phases of the aeronautical development work being carried on there by the engineering division of the Army Air Service.

The inspection trip began at 10 a. m. and ended at 1 p. m., when luncheon was served in the auditorium. This was followed by an address of welcome made by First-Lieut. E. E. Aldrin, secretary of the Engineering School, and by 10-min. talks on Magnesium Castings, Fatigue Tests, Air-Cooled Engine Development, Generator Problems Due to Crankshaft Vibrations, Earth Inductor Compass, and Aircraft Armament Problems, made by S. Daniels, R. R. Moore, Lieutenant Bruner, George P. Luckey and D. C. Maier respectively.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S. A. E. Standards Committee and other standards activities are reviewed herein

LEATHER-SUBSTITUTE STANDARD NEEDED[1]

Manufacturers Willing to Cooperate—How Physical Properties Are Tested

An obvious need exists for standardizing a product that is used so extensively as is artificial leather. The automobile builder cannot be expected to be conversant with all the details of the fabrication of the material and with its general physical properties, and, because of lack of ready availability of this information, he may often pay more than is necessary for the type of material he needs for a particular purpose. Facts of importance to the consumer are the total weight of the material per square yard, weight of coating material, and weight, thread-count and construction of the fabric. These data can be secured by comparatively simple analysis that the consumer himself can make if he desires. Knowledge of the tensile-strength of the material to be used for certain purposes is also important.

The usual procedure for determining the tensile-strength of fabrics, including coated fabrics, is based on the use of a 1-in. strip carefully cut and threaded, but this test is by no means considered standard by all users of artificial leather. A number of modifications have been adopted by various consumers and the lack of a standard for tensile-strength often causes misunderstanding as to just what is desired by the consumer. The adoption of a definite procedure for this test would be of mutual benefit to manufacturer and consumer; just such information is needed so that purchases may be made intelligently. Manufacturers of reputable products are anxious that consumers shall have and use such information, and are willing to be of service in this respect. The consumer should know just how any material that he contemplates purchasing will stand up under this and other tests.

The need for standardization of tests and of specifications for leather substitutes cannot be over-emphasized in view of the important place that such materials occupy in the automobile industry. The Passenger-Car Body Division of the Society of Automotive Engineers no doubt would act as the medium for the adoption of standards and specifications, and the results of such an effort would certainly be of benefit to all concerned. With this thought in mind, it is believed that it will be of interest to consider briefly the development of the leather-substitute industry, the process of manufacture of the product and the methods in use for testing its physical properties.

Growth of Manufacture and Use

The first patent for a leather substitute was issued in England about 1855 and the basic principle of that patent is used in the manufacture of the most popular and durable type of the material today. The industry was started in the United States about 1890. It has grown so rapidly that, according to the Census of Manufactures issued by the Department of Commerce, the value of artificial leather manufactured in 1923 was approximately $33,500,000, an increase of 116.3 per cent as compared with 1921. With such rapid expansion, the manufacturers were confronted with many problems. Much time and money have been expended in improving manufacturing processes, developing new types of material and improving the quality and durability.

Approximately 9,888,800 sq. yd. of leather substitutes was used by the automobile industry in 1921. The consumption in 1923 was 18,479,700 sq. yd., an increase of 87 per cent in 2 years. Besides its use for upholstery, it finds other extended uses in the industry, from spring-boots to tops and from radiator covers to tire covers. The varieties range from light-coated sheetings to heavily-coated sateens, ducks, drills and moleskins. Artificial leather is not merely a cheap substitute for real leather; tests have shown that for many purposes it is superior to other materials, even disregarding the cost advantage. Much harm has been done to the leather-substitute industry, however, by misuse of the material and great need exists for education of the consumer

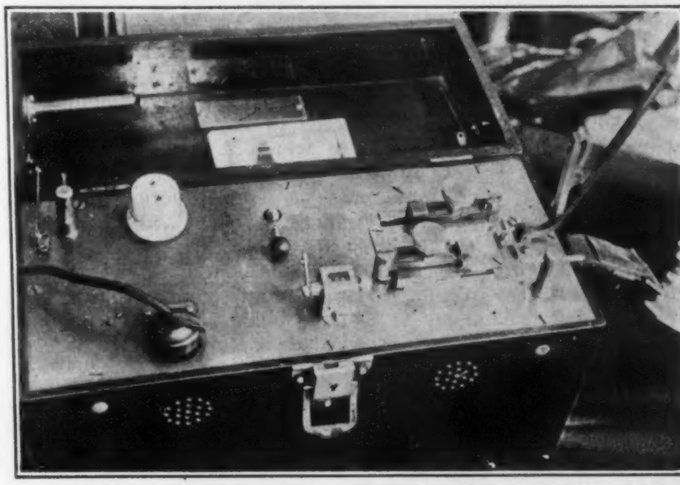


Fig. 1—Machine for Determining the "Scrub" of Leather Substitute

A Sample of the Imitation Leather To Be Tested Is Clamped by Opposite Edges in the Two Sliding Heads Near the Right Top of the Machine and Is Folded Under a Metal Rider Attached to the Hinged and Weighted Bar. When Lowered into Horizontal Position, the Bar and the Rider Press Certain Sections of the Coated Surface against Adjoining Sections While the Two Sliding Heads, Reciprocated in Opposite Directions by an Electric Motor, Stretch the Fabric and Scrub the Surface. The Action Simulates the Old Hand-Scrub Test but Is Much More Uniform. This Machine Has Been Used With Success for a Number of Years and the Value of the Results Is Unquestioned

in its proper use. The manufacturer should know, from his experience and development work, whether or not a certain material will be satisfactory for the use intended by the purchaser, and the purchaser should trust the advice and recommendations of reliable manufacturers and not demand material whose serviceability is questionable. New conditions of use are arising constantly and the manufacturer must meet them; it is also his aim constantly to improve the quality of his product. To do this, it is necessary to have a competent technical staff constantly working on the product. The manufacturer of the material requires highly experienced workmen.

How Leather Substitute Is Made

The manufacture of artificial leather[2] consists essentially of spreading on suitable base fabrics a composition of nitrocellulose and organic solvents, with which is mixed a softener, usually castor oil, and pigments to give the desired colors to the finished product. The smoothly-coated fabric, after being inspected carefully, is embossed to give it the desired grain by passing it through heavy embossing machines, which may be of either the roller or the flat-bed type. The material is then ready for a final rigid inspection

[1] By E. H. Nollau, chemical superintendent, Fabrikoid Division, E. I. du Pont de Nemours & Co., Newburgh, N. Y.

[2] See *Automotive Industries*, Aug. 2, 1923, p. 224.

before being shipped, unless it is desired to apply a finishing-coat, either of the same color as the base coat or of a contrasting color. This is often done to produce Spanish or two-tone finishes that duplicate those applied to genuine leather. The variety of grains, colors, shades and finishes in which the material can be manufactured, is practically without limit.

Quality Maintained by Accelerated Tests

The testing done by the manufacturer does not end with the raw materials; the same careful attention is given to the finished product. Uniformly high quality is of utmost importance to most manufacturers as well as to the consumer. For this reason a number of tests have been developed as a result of considerable study and much laboratory work.

Quality is ordinarily considered from the standpoint of (*a*) general appearance of the material with regard to color, finish and uniformity, with certain allowable variations, and the "feel" and pliability and (*b*) initial quality of the coating on the fabric and, what is perhaps most important, the durability of this coating. The ideal test is, of course, a real service test but this is not always practical although progressive manufacturers are always carrying out service tests as part of their control work on the finished product. To get quick results, accelerated tests have been developed; to make these of real value, every effort has been made to interpret the results in terms of actual service. Conditions to which the material is subjected in the test should be as nearly as possible like those to which it will be subjected in service, but exact duplication is not possible because, in general, the conditions must be more severe in an accelerated test. Among the important tests ordinarily applied to artificial leather are (*a*) scrub, (*b*) deterioration in artificial aging, (*c*) anchorage of the film to the fabric, (*d*) cold-test, (*e*) tensile-strength and tearing-strength and (*f*) fold-test. Analysis is usually made also to determine the construction of the material, that is, total weight, weight of coating and weight of construction of fabric.

Scrub Test

This is probably the most important single test for leather substitute and has been used in the industry for many years. It was originally carried out by grasping a piece of material between the hands so that the thumbs lay on top of the goods and parallel to each other and about one-half inch apart. The hands were then brought together and, gripping the goods firmly, the material was scrubbed much as a fabric might be washed. The number of complete forward and backward cycles, counting the two motions as one cycle, before the coating on the fabric showed a break, was called the "scrub."

It is evident that the personal equation enters into this test and that it would be difficult to reproduce results even on the same piece of material. For this reason, an effort was made to develop a machine-test in which the material could be subjected to the same conditions as in the hand-scrub but in which they would be uniform at all times, thus eliminating the personal equation and allowing results to be reproduced with uniform accuracy. The scrub machine, illustrated in Fig. 1, has two heads in which the sample is clamped. These heads are reciprocated in opposite directions, power being furnished by an electric motor. The sample to be tested folds under a rider hinged to a bar that carries a weight at its upper end. The rider presses certain sections of the coated surface against adjoining sections while the reciprocating action of the heads stretches the fabric and causes the surface to be scrubbed in the same manner as in the hand-scrub test but with much greater uniformity. The machine-scrub test has been used with success for a number of years, so there is no question regarding the value of the results.

Artificial Aging

This test is carried out by first subjecting the material to the scrub test and noting the result as the "initial scrub." The sample is then aged in an electrically-heated constant temperature oven at 150 deg. fahr. for a period of 4 weeks, after which the aged sample is again subjected to scrub test. The reduction in "scrub" is noted as the per cent deterioration; for example, if the original scrub was 100 and the scrub after 4 weeks' aging at 150 deg. fahr. was 25, the deterioration would be noted as 75 per cent.

This test is of prime importance, because, regardless of how good the initial quality may be, the material must age well if it is to give good service. The importance of initial quality can easily be over-rated, but the aging quality is of paramount importance.

Anchorage of Film

The test to determine security of the anchorage of the film to the fabric is also an old one and familiar to both manufacturers and consumers of leather substitute. In the past, the test consisted of determining by hand the pull required to loosen and strip the film from the fabric. The strength of the film has an important influence on the anchorage when tested by hand; thus, taking two pieces with equal anchorage, the one having the stronger film will appear to have the lower anchorage because the high tensile-strength of the coating permits it to be torn free from the base more easily than a film that breaks when pulled. Hence, this is another test in which the personal equation entered considerably, and for this reason a mechanical test was developed that permits results to be reproduced with considerable accuracy.

Briefly, the test consists of fastening a piece of cotton sheeting, by a suitable adhesive, to the coating on the leather substitute, a satisfactory procedure having been developed to give uniform results. After the sample has been prepared, the two fabrics are separated at one end of a strip 2 x 8 in. and pulled apart for a distance of about 2 in., care being taken to have the film of the original material adhere to the sheeting. The 2-in. portions that have been pulled apart are then narrowed to a width of 1 in. and the free ends inserted into the clamps of the machine used for making tests of tensile-strength. The results are reported as pounds necessary to strip the film from the fabric in a test piece 2 in. wide. This procedure has yielded very satisfactory and consistent results.

As the fact that various protective coatings crack at low temperatures when subjected to sharp bending is well known, the cold-test is carried out to determine at approximately what temperature the material under test will crack. The test consists essentially of allowing a sample to remain at a certain temperature for a definite time, then folding it sharply and determining whether or not it cracks. Various modifications have been used from time to time, so no definite procedure can be outlined.

Tensile, Tearing and Fold Tests

The tensile-strength of leather substitute is determined by machines designed especially for the purpose. These are readily available. The general procedure in this test is so well known that it is not necessary to describe it. The information given by the test is of importance if the material is to be subjected to considerable strain in service.

Tearing-strength is determined by the same machine that is used for determining tensile-strength. To carry out the test, a tear is started in the material in the direction in which it is desired to measure the tearing-strength. The material at one side of the tear is inserted in the upper jaw of the machine and that on the opposite side in the lower jaw. Since the force required to tear a woven fabric is irregular, it is necessary to take a graph of the stress applied to the goods in this test. The final figure is best obtained by using a planimeter to measure the area between the axis and the irregular line of the graph.

The fold test is important in determining the ability of a leather substitute to withstand repeated folding. It is carried out by folding a sample of suitable size according to a definite procedure and inserting it in a special machine, which is driven by an electric motor and operates a vertical plunger that folds the goods repeatedly until a crack appears on the folded edge.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

RIDING-QUALITY MEASUREMENTS

Problems and Instruments—Accelerometers and Seismographs Differentiated

A number of papers have appeared in the last year or so on the subject of riding-qualities and their measurement or definition. These various papers show so wide a range of viewpoints that the reader is in danger of being somewhat confused as to what it is all about. This is not intended as a criticism of any one of the several papers but merely emphasizes the complex nature of the problem and the need for some common ground on which to discuss it. The spring-suspension engineer is aiming at improvement in the conditions that involve motions of relatively large magnitude, as are also many of these interested in the shock-absorbers. Others whose interests center on shock and engine vibrations are considering the minor motions down to amplitudes of 0.001 in. or so. These differences in viewpoint are apparent particularly in the design and discussion of instruments for the measurement of something to indicate riding-qualities.

Possibly a brief discussion of some of these different ideas in their relation to each other may scatter some of the fog.

In general three sorts of measurements might be made with the expectation that they will indicate something about riding-qualities as affecting the passenger. These are measurements of (*a*) displacement that is, of the actual motions aside from uniform speed ahead to which the passenger or the car body is subjected; (*b*) accelerations, which are proportional to the actual *forces* which the passenger feels through the cushions, floor or other parts of the car with which he is in contact and (*c*) *rates of change* of the accelerations or forces.

Instruments have been devised to measure both the motions (*a*) and the accelerations (*b*) and some combinations of them, sometimes without a very clear analysis of just what was being measured. So far as we have noted, no attempts have been made to measure directly the third quantity (*c*) rate of change of acceleration. We may owe an apology for the discussion that follows, as none of the material is original or new, and the quantitative discussion is for the most part capable of rigid mathematical treatment; the latter, however, we shall not attempt to include, but shall rather try to explain the simple mechanics of some of the problems without recourse to mathematics. Measurements of displacement may be made by a general type of mechanical device, often called a seismograph as applied to earthquake measurements.

The general term *accelerometer* is applied to a wide variety of instruments for measuring the rates of acceleration. As a matter of fact, the essential difference between these two classes of instrument is so slight that the same instrument may be an accelerometer when used for some purposes and an equally good seismograph when used for another. Either instrument in its simplest form consists of a weight supported on a spring or suspended in such a way that when the support is moved the weight, due to its inertia, moves relatively to the support. Some means must be provided for indicating or recording the relative motion of the weight and its support. It may be simpler to consider one or two typical forms of instrument. The different forms of instrument are almost as many as there are designers; all, however, involve the same principles.

Suppose it is desired to measure vertical motions of a chassis. A weight sliding on a suitable guide and supported by a spring will serve the purpose. A marker attached to the weight may record on a scale attached to the frame carrying the spring support.

Difference Between an Accelerometer and a Seismograph

Now, when is this device a seismograph and when is it an accelerometer? also when is it neither? If the spring is very long or, in other words, if the initial displacement of the weight under the force of gravity is considerable, say 2 or 3 ft., the weight when displaced and allowed to oscillate freely, will have a long period. Obviously, if the device is placed on a vehicle and subjected to small motions of 2 or 3 in., with a short period of not over 1 sec. or so, the suspended weight will not move very much during the short period of the car motion and will therefore act almost as a fixed reference-point and the record of the motion of its support will be nearly a correct record of the actual motions of the chassis, provided always that the weight is damped by some dashpot device to keep it from oscillating too freely. The essential requirement for such an instrument is therefore a long initial-displacement or what amounts to the same thing, a long time of free swing, that is, long as compared with the time required for the motions that are to be measured. Practically, how long this factor should be depends on the accuracy required, but the period should probably be five times as long as that to be measured. A seismograph with a 5 sec. period can be used to measure chassis vibration of a 1-sec. or less period.

If, on the other hand, it is desired to measure the vertical accelerations, instead of motion, the same general type of device can be used, but with a very different selection of parts. Accelerations would be measured correctly if the weight were fixed immovably to the support by some device that would measure or record continuously the force required to hold the weight in place. Since most practical recording devices applicable to the case in point, and to most others, for that matter, must have some relative motion of the weight and its support to make a record, it is practically necessary to mount the weight on a stiff spring or the equivalent, such as an hydraulic diaphragm, and use the small relative motion as a means of recording the forces that measure the accelerations.

Small relative motion for a given force means a stiff spring and a high natural period of vibration of the weight. In a good accelerometer this free period should be several times as short as the period of any of the motions for which measurements are to be made; expressed differently, the maximum relative motion of the weight and its support should be several times less than the shortest range of motion for which accelerations are to be measured. Thus, if motions for which accelerations are to be measured cover only 0.001 or 0.002 in. the accelerometer spring must not allow a displacement of more than a few ten thousandths. If, on the other hand, the horizontal acceleration of a car, or the braking deceleration is to be measured, the motions extend over many feet and over several seconds of time and an accelerometer for this purpose can have almost any displacement desired and a natural period of 1 or 2 sec. Most of the serious errors in the design and the use of accelerometers have come from failure to appreciate the importance of short periods or a short range of motion of the weight element when used for high-period accelerations as in the case of impact. It is not possible to reduce the

relative motion indefinitely, inasmuch as the motion multiplied by the average force involved is a measure of the amount of work that can be utilized to operate the recording mechanism. In the case of a mechanical device, the parts will have some mass and an appreciable amount of work must be done to move them. If electrical or optical devices can be used, much less work is required and for very short-period motions one of these is almost necessary.

This discussion is intended to do no more than emphasize the fact that any research engineer who has a problem of measuring either displacements or accelerations should make a careful study of the conditions that must be met by any measuring instrument for these purposes. In many instances a few hours of careful work of this kind would have saved months of costly and fruitless labor. If a seismograph is needed, its period and range of motion must be *long enough.* If an accelerometer is required, its period and range of motion must be *short enough.* If not, the instrument will be neither a seismograph nor an accelerometer, but a prevaricator.

OIL DILUTION AND CONTAMINATION

Data on Analysis Made of Samples Received from All Parts of the Country

In the May issue of THE JOURNAL mention was made in this column that the Society has made arrangements through the headquarters of a number of companies producing passenger cars and trucks to secure samples of diluted and contaminated crankcase-oil. To make a survey of the crankcase-oil situation covering nearly all of the Country, requests for samples, with instructions and a form pertaining to data required, were sent out. These samples are now arriving at the Bureau of Standards. There the samples are carefully classified and indexed to obtain reliable results. The exact analysis to which these samples are subjected is here stated exactly as given in a letter by Dr. George K. Burgess, director of the Bureau of Standards:

> Percentage of dilution is determined by the capillary funnel method and the water separated and measured.
>
> A 10-gm. sample of the oil is diluted to 100 cc. with light naphtha, allowed to precipitate and filtered. The precipitate is recorded as "insoluble material." The insoluble material is extracted with benzol and the extract recorded as "asphaltenes." This material is probably a measure of the deterioration of the oil due to tendency to oxidize.
>
> The benzol insoluble is ignited at low temperature, approximately 700 deg. cent. (1292 deg. fahr.) and the loss recorded as "carbon." This quantity obviously includes other combustible material such as organic dust, fibers and the like, though probably the amount of such materials is small.
>
> The incombustible residue is recorded as ash. This consists of metallic oxides or other compounds and silicates. The ash always has the reddish brown color of iron oxides.
>
> The above examination requires only half of the sample.
>
> Complete chemical analyses will be made on some of the samples. However, this analysis is costly and time-consuming and will be made on such individual or composite samples as seem, in view of the previous work and the information regarding service conditions, to promise valuable information.
>
> The additional tests that may be made will be dictated largely by the findings in the tests now contemplated.
>
> Samples of all the oils will be available for such additional tests as may seem advisable.

In the meantime, the Research Department of the Society would welcome any views that members may care to give in connection with this work.

EFFECT OF GRAIN ON STRENGTH OF STEELS

THE variation between the properties of samples of metal taken in different directions is not found in the strength but in the toughness and the ductility. No sound evidence appears that the maximum stress of the steel, when tested in different directions with respect to the grain, varies at all. The evidence as to the influence of the grain upon the elastic-limit is vague and contradictory, except in the one respect that it indicates the influence to be very small. On the other hand, the direction of the forging or rolling grain affects very materially the values obtained for elongation, reduction of area, notched-bar test and capacity to bend. The variations can be illustrated successfully in various ways, but they become very obvious when the ordinary routine mechanical tests are carried out upon materials orientated in different ways with respect to the direction in which the metal has been elongated by either the forging or the rolling process.

The test results obtained from the series of specimens in different stages of forging showed first, the remarkable uniformity in the values for elastic-limit, yield-point and maximum stress; second, the increasing discrepancy between the Izod value obtained from the longitudinal and the transverse specimens and, third, the regular increase in the notched-bar value in the longitudinal specimens as the forging progresses in amount. Whereas the Izod impact value of the longitudinal specimen of the third forging after normalizing was 74 ft-lb., that of the transverse specimen amounted to only 29 ft-lb. In the case of the first forging the figures were 34.0 and 27.3 ft-lb. respectively. The fatigue tests on all the specimens were made by the same methods. The Wöhler type of loading was employed throughout, and the fatigue values were obtained by the direct endurance method. The general trend of the results was definitely to show that the difference was not very large between the fatigue strengths of specimens taken parallel, and at right angles, to the grain of the material, but that in all instances the difference was in favor of the longitudinal material. The discrepancy between the longitudinal and transverse strengths was not so great as has been suggested. It is worthy of notice that even the transverse specimens have a kind of "longitudinal" grain. Instead of the fibers of the steel that compose the grain being cylindrical threads, they appear to be more or less flat and of the nature of ribbons.

Surveying as a whole the results that have been obtained, it would appear that steel or iron is not exactly as strong in fatigue when stressed in specimens whose axis is at right angles to the grain of the material as when stressed in specimens in which the axis is parallel to the grain of the material. The difference in strength between the two directions is, however, not very great. The maximum difference observed in the experiments that have been carried out is 16.7 per cent.—From an abstract in *Engineering* (London) from a paper by Leslie Aitchison and L. W. Johnson, before Iron and Steel Institute.

Voltage Regulation of Automotive Electrical Systems

By DALE S. COLE[1]

MILWAUKEE SECTION PAPER *Illustrated with* CHARTS AND PHOTOGRAPH

ABSTRACT

PROGRESS made in the development of electrical equipment to serve adequately the needs of motorbus service is reviewed. Electrical loads on motorcoaches are comparatively high, including the usual head, tail and dash lamps, body-marking and destination lamps and buzzer systems. As more and more electrical energy is used, the source of supply and its control become relatively more important. Not only does the electric generating system have to meet the demands of battery charging, but it should be able to carry the connected load with no battery in the circuit. This means that not only is sufficient energy necessary, but the voltage must be regulated in such a manner that the battery can be charged without endangering the life of the lamps because of excessive voltage, and no flicker in the light from the lamps must be perceptible. All these results must be attained under conditions of variable load, variable speed and the changeable temperatures encountered in service.

Voltage regulation is the latest development in the electrical control of an automotive generating system and the author describes it, together with other methods. The 12-volt voltage-regulator employed to accomplish regulation is considered in detail, it being designed to furnish regulated voltage energy to battery and lighting circuits on motor vehicles; to maintain the voltage within the limits required for sufficient, steady and non-flickering light from connected lamps; to assure long lamp-life by preventing excess voltage; and to provide the tapering charge, beneficial to the battery, which results automatically from regulated-voltage charging. The outstanding advantages of voltage regulation are summarized.

VOLTAGE regulation is the latest development in the electrical control of an automotive generating system. The very rapid development of the modern motorcoach has been accompanied by many improvements in equipment. One of the most interesting of these is the progress made in electrical generating systems which assures sufficient light to make the luxurious coaches attractive by night as well as by day, whether the vehicle be standing at the curb or running over its route. The universal acceptance of the voltage-regulated system is paralleled only by the popular enthusiasm with which the public has received and is using the highway coach.

Lighting loads on motorcoaches are comparatively high, including the usual head, tail and dash lamps, body-marking and destination lamps and loads due to buzzer systems. In some cases, greater loads have been proposed such as electric fans, curling irons on sleeping coaches and even electrical heating of the coach. In addition, a storage battery must be charged. As more and more electrical energy is used, the source of supply and its control become relatively more and more important. Not only does the electric generating system have to meet the demands of battery charging, but the generator should be able to carry the connected load with no battery in circuit. This means that not only is sufficient energy necessary, but that the voltage must be regulated in such manner that the battery can be charged without endangering the lamps from excessive voltage. Further, the voltage on the lamps must be steady, with no perceptible flicker in the light. These results must be attained under conditions of variable load, variable speed and at changeable temperatures encountered in service.

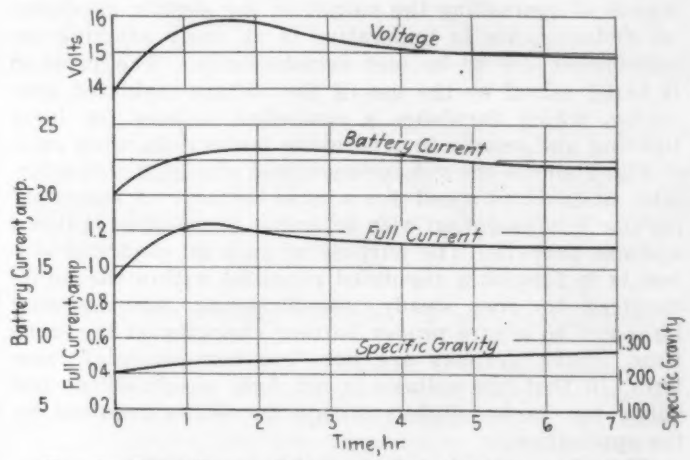


FIG. 1—THIRD-BRUSH GENERATOR CHARGING CHARACTERISTIC
On Protracted Charging, As the Battery Takes Its Charge and Its Voltage Increases, the Voltage of the Generator Tends To Increase, Keeping Sufficiently above the Battery Voltage To Force a Fairly Uniform Amount of Current Through the Battery. The Value of the Current Is Affected by the Setting of the Third Brush on the Generator. This Type of Equipment Has Properly Been Termed "Current Controlled," Its Chief Characteristic Being a Fairly Constant Charging-Rate Regardless of Battery Conditions. This Curve Was Obtained at Constant Speed, for a Large Battery

THIRD-BRUSH-CONTROLLED GENERATOR

It is current practice in automotive installations, at present, to use the familiar type of third-brush-controlled generator for supplying energy to the storage-battery and the lights. The third-brush generator tends to maintain a fairly constant rate of battery charging current at all times.

Fig. 1 shows the third-brush generator charging-characteristics, at constant speed, for a large battery. On protracted charging, as the battery takes its charge and its voltage increases, the voltage of the generator tends to increase, keeping sufficiently above the battery voltage to force a fairly uniform amount of current through the battery. The value of the current is affected by the setting of the third brush on the generator. This type of equipment properly has been termed "current controlled," its chief characteristic being a fairly constant charging rate regardless of battery conditions. The third-brush generator being available and in common

[1] Research engineer, Leece-Neville Co., Cleveland.

use, motorcoach builders naturally applied it for use with heavy continuous loads where the conditions were entirely different from those usually encountered in the field of operation of passenger cars.

The tendency for the third-brush system in continuous service is to charge at too high a rate when the battery is well up in charge, and to furnish insufficient energy when the battery is in a discharged condition. These facts were soon emphasized in the motorcoach installations, where the driving schedules vary from slow speed and frequent stops, in city service, to the fairly constant, high-speed continuous schedules on interurban and cross-country routes. It was soon recognized that some other means of controlling the output of the electric generator on motorcoaches is imperative if all their exacting requirements are to be met satisfactorily. The problem is being solved by the use of the voltage-regulated generator, which furnishes a controlled voltage for lamp lighting and results in a tapering battery-charging rate.

Fig. 2 shows the voltage-regulated charging-characteristic, at constant speed, for a large battery. A somewhat popular misconception with reference to voltage-regulated systems prevails. The purpose of such an electrical system is to furnish a regulated potential within the limits required to give steady, non-flickering, non-changing light and to assure proper battery charging at the same time. Such systems are not "constant-potential" systems, in that the voltage is not held absolutely at one value, but varies slightly within the limits required by the application.

While the motorbus is probably immediately responsible for the present demand for and interest in voltage-regulated generators, one manufacturing company pioneered in this development during the war when it produced voltage-regulated generators for lighting the sights of anti-aircraft gun-carriages. These guns were mounted on trailers and were parked in position. There was no engine to drive a generator, and no battery was available. No means were provided for charging batteries in the field. This generator was hand driven and maintained the steady light required, without flickering, for the accurate reading of various vernier scales; at the same time, it did not endanger the lamps from excessive voltage. It was a self-regulating unit, without a battery. Its advantages were soon appreciated by aeronautical engineers and it was applied to airplanes, with some refinements, so that the radio apparatus is now operated from the system, this being a very exacting requirement. Army airplanes of all types and the night flying airplanes of the United States Air Mail Service are equipped with similar apparatus. The round-the-world flyers used such units on their epoch-making flight.

Voltage Regulation

The subject of voltage regulation divides itself properly into two divisions, (*a*) constant-voltage systems and (*b*) voltage-regulated systems. By "constant voltage" is meant a practically unchanging terminal potential within very close limits, say 0.3 volt or less, as in the case of airplane radio installations, under varying conditions of load, speed and wide extremes of temperature, such as may be encountered in the air. "Voltage regulation," as commonly applied, refers to a system that regulates within somewhat wider limits, such as those required on a motorbus or a motor truck for battery charging and lighting service where the main requirements are to keep the battery charged and to supply sufficient, steady light without flicker. Immediately the manufacturer is circumscribed by limiting conditions. On a 12-volt system, the lamps should be operated at approximately 14.5 volts for maximum life, and yet a voltage of 15 volts and sometimes more is required to charge the batteries used. Obviously, a compromise generator voltage is necessary.

Automotive Electrical Systems

A very brief history of automotive electrical systems, leading up to the development of the voltage-regulated system, is of interest. In general, the shunt-wound generator is best suited to automotive requirements, because of its inherent characteristics. The series and the compound-wound generators, two other well known types of direct-current machine, have series windings, and this fact alone makes them generally unsuitable.

In a simple shunt-wound generator, the field winding consists of a comparatively large number of turns of small-sized wire. This winding is connected directly across the armature, being thus in parallel with the armature and with the external circuit. As a result of this arrangement, variations in the current in the external circuit do not react directly on the voltage. Such variations have a secondary effect and, within the working range of industrial operations, the shunt-wound machine is relatively a constant-potential generator. Usually, however, it is driven at somewhere near constant speed. An increase in the external current causes an increase in the armature current. The armature current is the sum of the external current and the small shunt-field current. As the armature current increases, the voltage drop in the armature is increased and the terminal voltage falls. The terminal voltage is therefore greatest at no load, and gradually falls off with increased load. Since the field winding is connected directly across the brushes, the drop in the terminal voltage causes a decrease in the shunt field-current that tends to diminish the field flux, and a smaller electromotive force is generated in the armature; so, the terminal voltage falls still lower.

Compound-wound dynamos can be regarded as shunt dynamos, the fields of which are strengthened when the load comes on by a few series turns of wire carrying the main current; but these are entirely unsuitable for battery charging. If used for this purpose and the engine speed decreases, the counter electromotive force of the battery may overcome the charging electromotive force of the generator; then, the generator would be no longer in opposition, but the battery and the generator would act together in a circuit of low resistance, causing a dangerously high current to result.

If a shunt-wound generator is used, the positive terminal of the battery should always be connected to the positive brush of the generator, and the shunt current in the field coils is always in the same direction, even when the main current is reversed. The electromotive forces of the battery and the generator are always opposed. When the main current reverses, the battery drives the generator as a motor, and the current cannot reach a dangerously high limit.

As to the effect of speed variation, assuming the load to be constant, if the generator is running without a battery in parallel a change in speed has a marked effect on the terminal voltage. When in parallel with a battery, a change in the electromotive force of the generator will cause a change in the armature current. If the speed drops, the armature electromotive force decreases and, with it, the armature current. Since the current in the external circuit is constant, the battery, if discharging, must give a greater current and the smaller the

current that is given by the dynamo becomes. If charging, a decrease in the generator current due to lowered speed causes a decrease in the current passing into the battery.

Change of Excitation

A change in the value of the field current has a similar effect to that of a change of speed. If we wish to charge a battery, the field current is regulated so that the generator voltage is slightly higher than that of the battery, and the current can be controlled by a field rheostat. To stop charging, the field current is weakened until the generator voltage falls to the value of the battery voltage. The battery is then floating on the line and may act as a pressure regulator. In the shunt-wound generator, we have, then, a machine whose output is affected by variations of speed and load, to say nothing of temperature, but which has some desirable characteristics. Inasmuch as present-day automotive electrical-apparatus is seldom sold on a temperature rating, this will not be considered and it will be assumed that the temperature effect on the generator is slight which is, however, far from the case in many instances.

The problem presented for solution is to furnish a generator of the shunt type, which will be simple and comparatively cheap and which can be used, safely, for lighting and battery charging on vehicles. Here, the third-brush generator enters.

It is believed that Edison first used the reaction brush in the 1880's and it was applied to automotive generators about 1912 by the company I represent. In the third-brush generator, one end of the shunt field is connected to an auxiliary or third brush. The third brush usually is placed behind and close to the leading main brush. The other end of the field is connected to the external circuit of the battery at a point of opposite polarity to that of the leading main brush. The field is thus in parallel with the armature and with the external circuit, as in the straight shunt-wound machine; but, by virtue of the use of the third brush, the voltage across the field is lower than the voltage of the main-brush terminal. Further, the third brush is placed so that the armature reaction, due to increases in speed and load, has a decided effect on the field voltage and, consequently, on the field current which, in turn, reacts on the terminal voltage of the generator and functions as current control.

The third-brush generator is known as a "current-controlled" generator, as compared with the voltage-regulated machines. When connected to a battery, this generator will give a substantially constant charging-rate, the tendency being to maintain the rate as the battery comes up in charge. The tendency on protracted charging is to maintain a voltage higher than the battery voltage, resulting in a comparatively high charging-rate at all times. This may result in trouble of various kinds on continuous high-capacity applications. As the battery takes its charge, the voltage rises and the charging rate tends to increase, thus causing more current to flow through the generator armature. The result is less armature drop and increased terminal pressure which, in turn, strengthens the field and tends to maintain a higher charging-rate and voltage.

The third-brush generator has served well as a low-cost generator for passenger cars, and has given satisfactory service. It has, however, several disadvantages, when applied to motorcoach requirements, among them being

(1) Overcharging batteries on long continuous driving, with attendant troubles

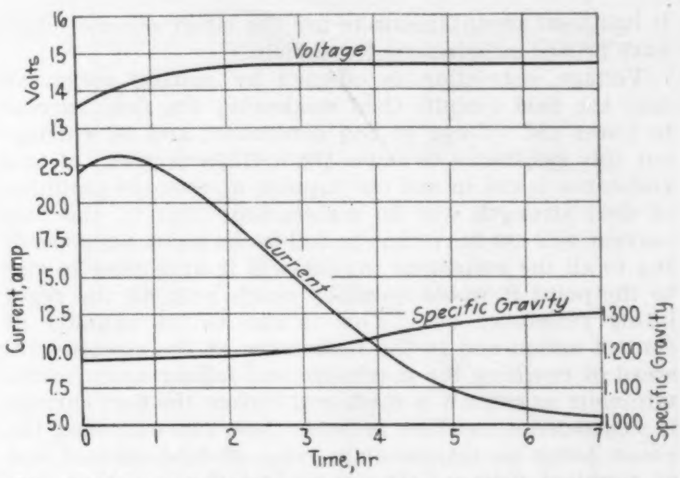


Fig. 2—Voltage-Regulated Charging-Characteristics Made At Constant Speed for a Large Battery

The Purpose of a Voltage-Regulated Electrical-System Is To Furnish a Regulated Potential Within the Limits Required To Give Steady Non-Flickering Non-Changing Light and To Assure Proper Battery-Charging at the Same Time. Such Systems Are Not "Constant-Potential" Systems in That the Voltage Is Not Held Absolutely at One Value But Varies Slightly within the Limits Required by the Application

(2) Undercharging batteries on slow, frequent-stop service
(3) Burning out lamps because of excessive voltage
(4) Reducing the length of life of lamps because of excessive voltage, especially where the third brush has been advanced to boost the output, due to conditions that may arise such as low water in the battery, loose connections, poor wiring or overloading
(5) Burning out field fuses and lamps if a battery connection becomes loose or disconnected
(6) Necessity for using the generator with the battery, and that it will not carry the lamp load alone at the rated voltage
(7) That it does not give a tapering battery charge but maintains a comparatively high, steady rate
(8) Because the lamp voltage usually is higher than it should be, which results in a waste of energy
(9) For the reason that energy is also wasted in maintaining a high-charging rate

The third-brush-controlled generator, as such, is not well adapted to motorbus and motor rail-car requirements where heavy loads are carried. The battery must be kept fully charged on all classes of service and, at the same time, it must be protected from overcharge. Lamp voltage must be held within the limits of safe operation.

Voltage-Regulated System

The voltage-regulated system consists of a shunt-wound generator, either with or without a third brush, and a regulating unit to maintain a controlled voltage under varying conditions of load, speed and temperature encountered in service. If the third-brush generator is regulated, the action of the third brush is such as to protect the generator automatically from severe overload.

If the straight shunt-wound machine is regulated, some overload protection should be used, such as an overload circuit-breaker. The third-brush voltage-regulated system thus consists simply of a generator, a reverse-current relay and a voltage-regulator element. The straight shunt-regulated system uses, in addition, an overload circuit-breaker. For a large majority of installations, the former is admirably adapted but, in some cases where high capacities at low speeds are required,

it has been advantageous to use the latter scheme. Both have proved satisfactory in service.

Voltage regulation is effected by cutting resistance into the field circuit, thus weakening the field current to lower the voltage of the generator; and by cutting-out this resistance to cause the voltage to rise. If this resistance is cut in and out rapidly, an average condition of field strength will be maintained; that is, the field current will not have time to fall to the point corresponding to all the resistance in, nor will it have time to rise to the point it would normally reach with all the regulating resistance out. This is due to the rapidity of contact action and to the inductance of the circuit. Instead of reaching the maximum and falling again to the minimum as contact is made and broken the field current is suspended somewhere between these two extremes, the result being an intermediate value of field current and of terminal voltage. If the contacts have a high frequency, the flicker of the lamp will be imperceptible; if the beat is slow and distinct, flicker will result. The

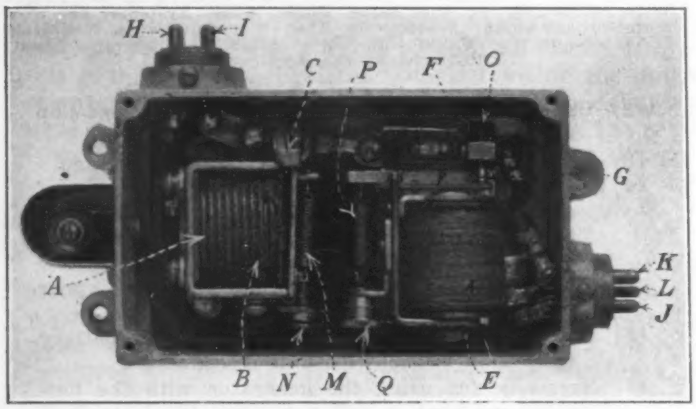


FIG. 3—THE VOLTAGE REGULATOR

This Device Is Designed To Furnish Regulated-Voltage Energy to Battery and Lighting Circuits on Motor Vehicles, To Maintain the Voltage within Limits Required for Sufficient Steady and Non-Flickering Light from Connected Lamps, To Assure Long Lamp-Life by Preventing Excessive Voltage and To Provide the Tapering Charging Rate, Beneficial to the Battery, Which Results Automatically from Regulated-Voltage Charging. Its Main Elements Are a Reverse-Current Relay or Circuit-Breaker and the Regulating Device, Which Comprises a Specially Constructed Magnet and a Pivoted Armature That Opens and Closes a Pair of So-Called Regulating Contacts

regulator must be designed so that it will respond to changes in the circuit; that is, it must function to raise the terminal voltage slightly under some conditions and to lower it under others.

In the regulator described later, an extremely high armature-beat is attained, and it is responsive to changes of load and of speed within the working range of any given system. The contacts handle the insetting and cutting-out of regulating resistance in an almost sparkless manner, so that they have long life and require little attention. A very strong spring-tension is used that results in a self-cleaning action on the contacts as well as making the instrument free from interruptions due to vehicle vibration. Metallic points are used; hence, no danger of changing adjustment due to contact wear exists as is the case with carbon and similar materials when used for contact points. The field circuit is never broken entirely; the regulating resistance is simply shunted. A unique arrangement of connections provides the desired regulating characteristics and flexibility of application and adjustment.

THE REGULATOR

The 12-volt voltage-regulator is designed to furnish regulated-voltage energy to battery and lighting circuits on motor vehicles, to maintain the voltage within the limits required for sufficient, steady and non-flickering light from connected lamps, to assure long lamp-life by preventing excessive voltage and to provide the tapering charging rate, beneficial to the battery, which results automatically from regulated-voltage charging. Two distinct elements are contained in the control box: First, as shown in Fig. 3, the reverse-current relay or circuit-breaker *A* which, in varied design, is in common use on almost all automotive electrical systems. This relay prevents the discharge of the battery through the generator circuit when the generator is not operating. It consists of a magnet, *B*, which operates an armature to open and close a pair of contact points, *C*. Second, the regulator element *D*, which comprises a specially constructed magnet, *E*, and a pivoted armature, *F*, which opens and closes a pair of contacts, *G*, called the regulating contacts. When the system is functioning properly, the following characteristics will be noted:

(1) Very little or no variation in the intensity of light from connected lamps on sudden changes of load or engine speed will be noticed
(2) A voltmeter, if connected across the load, will show a steady reading
(3) Little or no sparking between the contact points of the regulator will occur
(4) The rate of vibration of the regulator armature will be steady and high. It will not "flutter" slowly back and forth, or stick in one position
(5) The variation of voltage with the load disconnected, that is, with no lights or battery in the circuit but with the regulator connected to the generator, will be very slight when the speed of the generator is raised or lowered rapidly, within the working range, above the point where the circuit-breaker contacts close and the regulator begins to operate

In the interior view of the voltage regulator, Fig. 3, two sets of terminal posts extending through the control box are shown. The two terminals *H* and *I* connect with the load; that is, with the battery and the lights. The other set *J*, *K* and *L* connect with a similar set of terminals on the generator by a three-conductor cable, provided with one triple-contact connecting-plug at each end. One of these three terminal posts *L* is smaller than the other two so that the cable plugs cannot be attached incorrectly. The cable terminals are locked in place securely by a metal protecting-sleeve that is threaded to fit similar threads on the terminal-post base, at the generator and at the control box, thus assuring a tight connection at all times. The regulator operation is not affected by any change in temperature that may occur under the hood of a motor vehicle in normal operation.

CIRCUIT-BREAKER AND REGULATOR ADJUSTMENTS

Spring tension on the spring *M*, produced by the screw and the locking nut *N*, provides an adjustment on the circuit-breaker. Relieving the spring tension will cause the contact points to close at a lower voltage and to open at a higher current value. The circuit-breaker setting is important on high-capacity generators, and should conform to the average service requirements as closely as possible. If the circuit-breaker closes at too low a voltage, a period of battery discharge will result, as it may be possible that the battery voltage is higher than the generator voltage at low speeds. If the circuit-breaker closes at too high a voltage, initially, a period of waste driving time will ensue during which the battery will not be charged, although the generator voltage is sufficient to drive through a charging current.

Two adjustments are provided on the regulator: (*a*) the adjustment of the contact point *G* by the screw *O* and its locking nut and set screw; and (*b*) adjustment of the spring tension of the armature spring *P* by the knurled locking-nut *Q*. It should be remembered that, on voltage-regulated systems, batteries automatically will take different ampere-hour charging-rates at various conditions of charge. If the specific gravity of the battery is low, the charging rate will be comparatively high, and will taper off to a lower value as the battery takes its charge. Battery specific-gravity and condition should be considered carefully before adjustment is pronounced as to whether a charging rate is too high or too low. It is being found necessary to educate users as well as service-station attendants on this point. Frequently, a voltage-regulated system will keep the battery fully charged to a point such that only a trickling current is passing and the user becomes disturbed, thinking the generator is not charging as it should. A check almost invariably shows the battery to be fully charged.

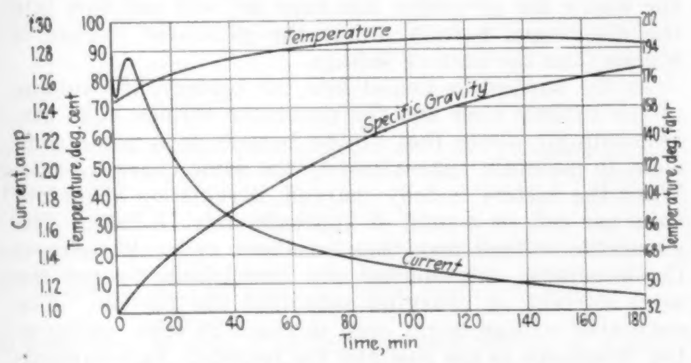


Fig. 4—Curves Illustrating the Desirable Tapering Battery-Charge
The Data Were Obtained in the Laboratory of the Battery Manufacturer, the Voltage Being Regulated Manually at a Very Constant Value. The Curves Are Very Similar to Those Obtained from Vehicle Applications of Voltage-Regulated Systems

If the points of a voltage regulator are held together, no regulating action takes place; the generator then operates under full field-strength at its maximum voltage for the given speed and load as a third-brush-controlled generator or a straight shunt-wound machine, as the case may be. The curves in Fig. 4, furnished by a representative battery manufacturer, illustrate the desired tapering charge. These curves were taken in the laboratory of the battery manufacturer, the voltage being regulated manually at a very constant value; they are very similar to curves obtained from vehicle application of voltage-regulated systems.

Charging Economics

The curves taken while a generator was running as a third-brush machine are shown in Fig. 1, and those taken when running as a voltage-regulated machine are shown in Fig. 2. These are simply specimen performances and apply to tests taken at certain brush and regulator-settings and under certain battery conditions; but, while the conditions were similar in the two tests and the curves illustrate the difference in operation, these must not be taken as applying specifically to all conditions. Many variables must be taken into account in the analysis of generator-performance curves, such as battery size and conditions, speed, temperature, brush settings and regulator settings. A generator designed to handle certain loads through certain speed ranges is built to meet specific conditions; so, the exact conditions under which tests are conducted are important if any intelligent analysis of performance is to be made. These curves were taken at constant speed on a large battery and show no rise in the third-brush-generator voltage which often results on protracted charging.

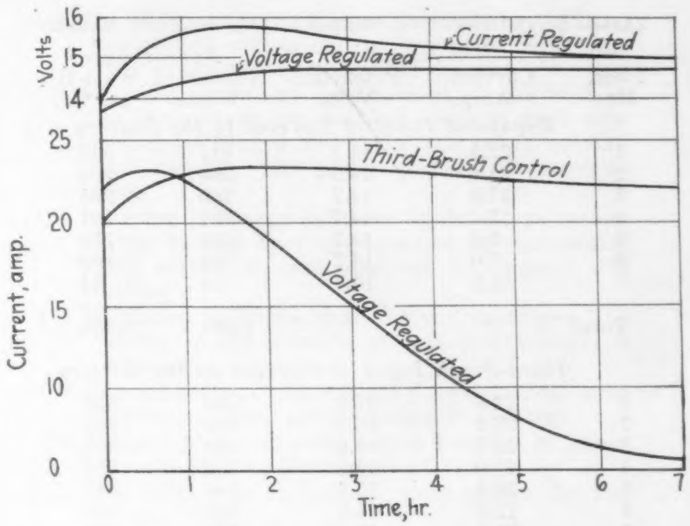


Fig. 5—Comparative Current and Voltage Curves
Data Were Obtained on Two Different Types of Machine, As Stated in Table 1

No reference has been made to generator efficiencies, but it will be appreciated that these vary with load, speed and design. In general, efficiencies on automotive generators are not important, because the amount of material it is possible to use is closely restricted and this naturally is reflected in the efficiencies. Likewise, little has been said with reference to generator temperatures. Usually, a manufacturer will rate the generator output on the vehicle while it is subjected to favorable cooling-conditions and such a generator, if run at full rated-load on the block, is very likely to overheat.

In Fig. 5, the current and the voltage curves for the two types of machine have been plotted for comparison. The curves were plotted from the data in Table 1. The average number of watts input for the two tests is shown by the curves in Fig. 6.

It will be noted that, for the same period, the total watt-hour input in the case of the voltage-regulated generator was 1388 and for the third-brush generator

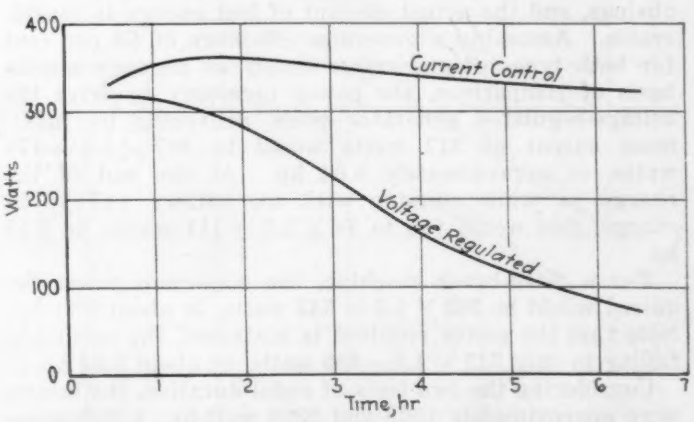


Fig. 6—Average Number of Watts Input for the Two Tests of Fig. 5
For the Same Period, the Total Watt-Hour Input of the Voltage-Regulated Generator Was 1388 and for the Third-Brush Generator It Was 2395 Watt-Hours; That Is, the Third-Brush Machine Delivered About 73 Per Cent More Power in the Same Time Than Did the Voltage-Regulated Generator. The Two Tests Were Made on the Same Battery at Approximately the Same Condition of Discharge on Starting. Beyond a Certain Point, Electrical Energy Cannot Be Used in Charging the Battery and Represents a Direct Loss

TABLE 1—COMPARATIVE CURRENT AND VOLTAGE VALUES

Time, Hr.	Average Current, Amp.	Average Potential, Volts	Approximate Number of Watts	Watt-Hr. per Hr.
Regulated Input of Current to the Battery				
1	22.5	14.1	317	317
2	21.0	14.5	304	304
3	17.0	14.7	260	260
4	13.0	14.7	191	191
5	9.5	14.7	139	139
6	7.0	14.7	103	103
7	5.5	14.7	74	74
Total			1,388	1,388
Third-Brush Input of Current to the Battery				
1	22.0	15.0	330	330
2	23.0	15.7	362	362
3	23.0	15.6	358	358
4	23.0	15.3	352	352
5	22.5	15.1	340	340
6	22.0	15.0	330	330
7	21.5	15.0	323	323
Total			2,395	2,395

it was 2395, showing a difference of 1007 watt-hr.; that is, the third-brush machine delivered about 73 per cent more power in the same time than did the voltage-regulated generator. The two runs were taken on the same battery at approximately the same condition of discharge on starting.

Beyond a certain point, electrical energy cannot be used in charging the battery and represents a direct loss. In his article entitled Finishing Charge Paramount[3], W. E. Dunn touched on this point as follows:

> Should the high charging-rate be continued, a point is reached where part of the current can do no useful work in charging the battery, so the excess energy breaks-down the water into gas and generates heat. The higher the temperature is, the greater the unnecessary wear and tear become. By the breaking-down of the water into its component elements, a process known as "gassing," the bubbles of gas coming out of the plate and rising to the surface erode the active material from the surface of the plate. . . . Therefore, . . . a definite control of the charging rate throughout the charge is required. Such a system should be automatic. . . .

The bearing of the foregoing facts on battery life is obvious, and the actual amount of lost energy is considerable. Assuming a generator efficiency of 50 per cent for both types of generator, simply as an approximate basis of comparison, the power necessary to drive the voltage-regulated generator when delivering its maximum output of 317 watts would be $317 \times 1.5 = 476$ watts, or approximately 0.64 hp. At the end of the charge, or while running with the battery well up in charge, this would fall to $74 \times 1.5 = 111$ watts, or 0.15 hp.

For a third-brush machine, the maximum power required would be $362 \times 1.5 = 543$ watts, or about 0.71 hp. Note that the power required is sustained, the minimum falling to only $323 \times 1.5 = 485$ watts, or about 0.64 hp.

Considering the two tests of equal duration, the inputs were approximately 1388 and 2395 watt-hr., a difference of 1007 watt-hr. or about 1.35 hp-hr. Translated into dollars and cents of cost, the yearly saving in power alone is of material importance on high-capacity continuous-service applications.

The voltage-regulated system is automatic, but the output of the current-regulated system usually is determined by the position of a third brush on the generator and by battery condition. The two types of equipment are designed for different purposes. The operation of the voltage-regulated system is different from the operation of a current-regulated system, as will appear from the following comparison.

The Two Electrical Systems Compared

When connected to the battery, the generator in the current-regulated system delivers a fairly uniform current at all times. The voltage of the generator is controlled by the voltage of the battery. In the case of a discharged battery, for example, a 12-volt battery, the voltage would be about 12 volts. To charge this battery, it is necessary to have a higher voltage than that of the battery itself. The predetermined amount of current for which the generator has been set will not flow into the discharged battery unless the generator voltage is higher than the battery voltage.

As the current is forced into the battery, the voltage of the battery rises and the generator voltage rises correspondingly above that of the battery to a point sufficient to maintain approximately the same charging rate. When the battery is fully charged, it registers about 2½ volts per cell, or a total of approximately 15 volts. The generator voltage may then be about 18 or 19 volts at the generator, considering the line losses, to get the same current or charging rate into the battery. The generator voltage might need to reach 20 volts, owing to the resistance in the line and the battery. In a current-regulated system, it is essential that the generator and the battery be connected securely when the generator is operating, so as to prevent too great a rise in the generator voltage. Open circuits, corroded battery terminals, insufficient water in the battery and other faults will cause a rise in the voltage of the generator which, if permitted to continue, will result in difficulties.

In the voltage-regulated system, assuming a voltage-regulated generator set for approximately 15.1 volts and that it is connected to a discharged 12-volt storage-battery, the battery registering 12 volts, the maximum current is determined by the design of the system and this is determined at the time of manufacture. The voltage of the battery rises, due to charging, and the generator output drops off until the generator voltage is about equal to that of the battery voltage; after this, only a trickling charge will flow from the generator to the battery.

Voltage regulation will build-up a battery quickly and protect it from overcharge, due to the fact that the voltage of the battery when charged is about equal to the voltage of the generator. Unlike the current-regulated generator, the voltage regulated-generator can be operated when connected to or disconnected from the battery. Since the voltage of the generator is controlled by the regulator, the lamps can be operated directly from the generator. This feature of voltage regulation assures light while the vehicle is in operation, whether the storage-battery is connected or not. The life of the battery is prolonged and the electrolyte does not decompose so rapidly as when being charged continuously by a current-regulated generator. In motorcoach service, where no two runs are exactly alike and where either traffic or highway conditions are severe, the advantage of the voltage-regulated system is recognized. Operation in city service, with many stops and starts or with intermittent periods of idling and full acceleration, formerly resulted in batteries receiving a charge insufficient

[3] See *Electrical World*, Nov. 29, 1924, p. 1162.

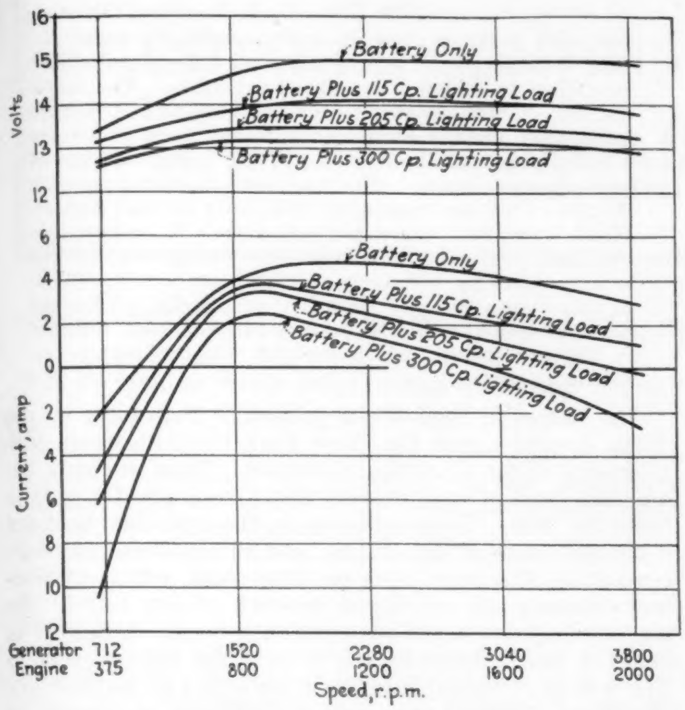


FIG. 7—PERFORMANCE CURVES OF VOLTAGE-REGULATED CITY-SERVICE
These Curves Were Obtained from Tests Made on Fifth Avenue Motorbuses in New York City under Exacting Conditions

to keep them in good condition for long periods of night operation. On the other hand, with current regulation, the long runs in country districts kept the generators charging continuously and at a high rate, which caused battery trouble.

As to the ability of a properly designed voltage-regulated system to operate on open circuit, while a generator is not required to operate under this condition in service, it may be expected to carry as few as one or two lamps without burning them out. One regulator now on the market will hold the voltage, on open circuit, within a range of less than 1-volt variation on speeds varying from the balancing speed, or the speed at which the generator delivers 12 volts on open circuit, to a speed of from five to seven times this balancing speed. The open-circuit or light-load test is a severe one, and it will indicate many points regarding regulator performance.

It is proposed to equip motor trucks with voltage regulation for head and tail lamps, without a battery. These systems will furnish adequate and steady light at engine speeds corresponding to 5 m.p.h. and upward.

If any voltage variation is to be permitted on loads, a slight drop is preferable to an increase. For instance, if a regulator be set at 15 volts on open circuit and, when the load is applied the voltage drops to about $14\frac{1}{2}$ volts and remains steady, this voltage is better suited to lamp operation than 15 or $15\frac{1}{2}$ volts and will result in longer lamp life. The compromise regulated voltage is closely related to the individual operating conditions of a particular installation.

SUMMARY OF VOLTAGE-REGULATION ADVANTAGES

(1) A tapering battery charge is provided which prevents overcharging the battery
(2) A slight reduction in voltage on load can be provided as a protection to lamp life
(3) Steady, non-flickering light is assured, either with or without a battery
(4) The lamps can be operated without a battery, preventing delays due to broken or loose battery connections and battery trouble
(5) A saving in energy results, because the battery is charged at the required rate; a high rate when discharged and a low rate when nearing full charge. The power saving is a material one
(6) A saving in energy delivered to the lamps results also, because they are operated at very nearly the correct voltage required for highest efficiency
(7) A saving in lamps, due to their prolonged life, owing to the absence of excessive voltage, is effected
(8) The condition of the battery does not affect lamp operation when the generator is running
(9) Danger of burning-out lamps because of excessive voltage is eliminated
(10) The battery is charged at more nearly the correct rate
(11) Prolonged battery life results
(12) Loose or corroded battery connections do not affect the operation of the lamps
(13) The battery electrolyte will not evaporate so rapidly
(14) Regulation is automatic

The voltage-regulated system has received the hearty approval of the most representative motorcoach builders and the enthusiastic support of the motorbus operators. An article entitled The Operation and Maintenance of the Motorbus[3], by J. B. Stewart, Jr., expresses an operator's view:

> One of the greatest advertisements and "passenger getters" in motorbus operation, in my opinion, is a well lighted motorbus. The General Electric Co. has made

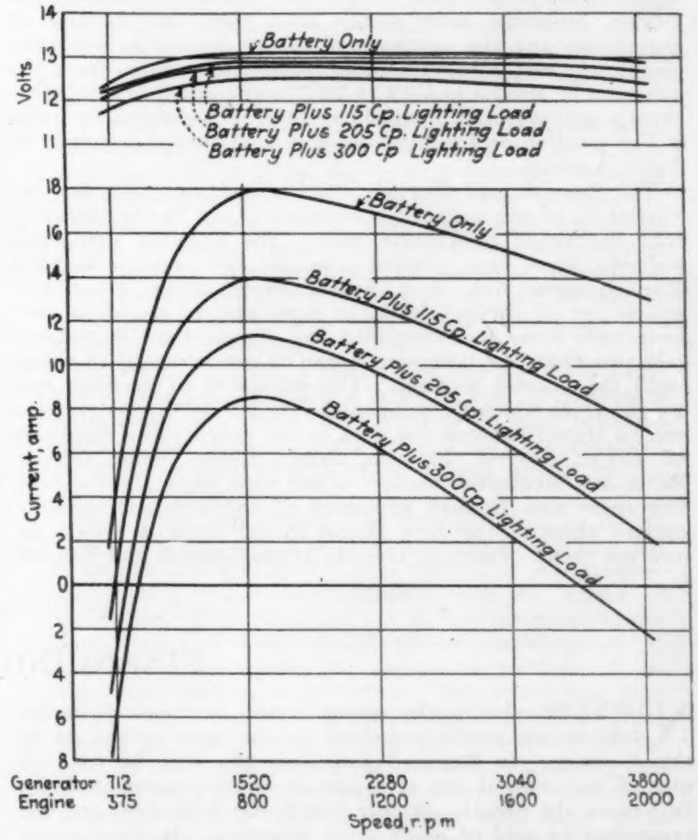


FIG. 8—OTHER MOTORBUS VOLTAGE-REGULATED PERFORMANCE CURVES
This Set of Curves Was Obtained on Fifth Avenue Motorbuses Under Conditions Similar to Those of Fig. 7

[3] See THE JOURNAL, October, 1924, p. 313.

a very complete study of lighting conditions in motorbuses and is ready to make studies and recommendations at any time that a request may be made. The design of the socket and lamp, however, and the selection of the proper type of reflector to give the best distribution of "foot candles" to secure the best illumination and to avoid shadows, are a very small part of the problem. It is a simple thing to say that the body lamps should consist of six or eight 32-cp. lamps, but when we come to the point of providing energy to light the lamps, we are facing a serious problem that divides itself into separate and distinct propositions, that is, interurban and city service.

It is my personal opinion that the battery should not carry any of the lighting load except for comparatively short periods of time when the engine happens to be shut down. The sole function of the battery, therefore, is to carry the lights during these periods and to furnish current for the starting motor. In interurban service, the problem is comparatively simple and resolves itself into the designing of a generator of sufficient capacity to carry the lighting load. The speed of the interurban motorcoach is usually high enough to drive the generator at a speed that will cause it to produce its rated output. In city service, with the numerous stops and slow-downs, it is rarely possible for the engine to operate for any length of time at a speed that will permit the generator to produce its rated output. It, therefore, becomes necessary either to introduce step-up gears or to design an armature that will produce the rated output at a lower engine-speed. In several instances the first scheme has been followed; but with some engines it is impossible to make the gear installation. The generator manufacturer is then compelled to design a low-speed armature. The introduction of the low-speed high-charging-rate armature introduced another complication in the form of battery trouble, owing to the buckling of the plates because of high charging-rates. This has been overcome through the use of voltage regulators and other similar devices. When our fleet consisted of some 32 motorbuses equipped with the standard type of generator, the battery-charging bill averaged $150 per month. With 42 motorbuses now in operation, practically all having late-type generators, the battery bill has been reduced to $25 per month, which includes all the repairs as well as charging.

The curves in Figs. 7 and 8, plotted from tests by the Fifth Avenue Coach Co., New York City, illustrate performance under exacting conditions. These are only examples of many such reports that are constantly coming from the field. The need arose in the motorbus field for a certain class of apparatus, and it has been met successfully. The work does not stop here, when satisfactory systems are operating on land, at sea and in the air, but improvements are constantly being made. It is believed that eventually the system for voltage regulation will be remarkable for its simplicity and satisfactory operation. Voltage-regulated systems are at present in service on 6, 12 and 32-volt requirements.

STANDARDS OF MEASURE

FOR over 300 years, from 1607 to the present time, the English system of measures has remained the fundamental standard of the people of Canada and the United States, becoming more firmly fixed with the increase of population and the development of the industries and commerce of these countries. For nearly 350 years, from the conquest of Mexico in 1519 to 1526 to the middle of the nineteenth century, the Spanish system of measures occupied a like position as the accepted and undisturbed standard of Latin America.

The Spanish and English weights and measures are but variations of one system whose origin is lost in the obscurity that surrounds prehistoric man. The Spanish *vara*, *pie*, *pulgada*, *libra*, *onza*, *adarme*, *cuartillo* and *azumbre* and the English *yard*, *foot*, *inch*, *pound*, *ounce*, *dram*, *quart* and *gallon* are all derived from the same ancient measures that have been developed, simplified and standardized by natural selection from the time men began to measure and to weigh until the present moment. The standards of measure and weight from which these Spanish-English units were derived can be traced through the ages in the weights and measures of Egypt, Assyria, Babylon, Japan, China, India, Greece, Rome and Mediaeval Europe to the time when the Spanish, Portugese and English explorers of the sixteenth century carried them to the New World in the form in which we now use them. The close identity of the Spanish and English systems proves their common origin. They are but variations of one natural system. The divisions of the units of length and weight are exactly the same, while the sizes of the units of weight vary only 1.4 per cent; the linear units, about 10.0 per cent. For many important uses Spanish and English weights are interchangeable.

Up to the nineteenth century standardization of weights and measures in Continental Europe had been confined to very restricted areas and small groups of users, to the family, tribe or principality, and was seldom extended to include a nation. The resulting diversity and confusion, unknown in America, made unification a necessity to meet the needs of modern industry and commerce. France, aided by the imperative necessity for reform and by the abnormal force of the Revolution, undertook the work in 1790 and succeeded in the next 60 years in bringing a new system of weights and measures, the metric, into extensive use in Continental Europe. The Governments of Spain and Portugal adopted the metric system between 1849 and 1852 and it was natural that it should be adopted at the same time by the governments of Spanish and Portugese America. For 75 years, from 1850 to 1925, this experiment to substitute the metric system for the fundamental Spanish system of measurement has been in progress in the countries of Latin America.—From a statement by S. S. Dale at First Pan-American Standardization Conference.

FINANCING CAR SALES

NOWHERE else in the world is the purchase of motor vehicles on credit practised to the same extent as in this Country. In England and Australia only between 15 and 25 per cent of the sales are on a time-payment basis. In France the practice is only now being developed, and the same may be said of many other countries. In Mexico and Cuba a rather high proportion is sold on time payments, but in South American countries, the Argentine for example, only a low percentage obtains. Automobile selling was on a cash basis in this Country up to about 1910, when the rapid growth of the manufacturing industry and the development of the sales organization brought several finance companies into the business. W. H. Alford, vice-president of the Nash Motors Co., estimates that 80 per cent of the car-owners of the Country have incomes of less than $2,000 a year.—*Eastern Underwriter.*

STANDARDS COMMITTEE DIVISION REPORTS

The following Division Reports will be submitted to the Standards Committee for approval at the Summer Meeting

STANDARDS COMMITTEE MEETING JUNE 18

Will Be Held at White Sulphur Springs during Summer Meeting of Society

Twenty-five recommendations will be submitted to the Standards Committee for disposition at the semi-annual meeting, which will be held at the Greenbrier, White Sulphur Springs, W. Va., on Thursday, June 18.

The recommendations to be acted upon are reviewed in this section of THE JOURNAL in order that those interested may have sufficient time to study them before the Standards Committee Meeting. Non-members of the Standards Committee or of the Society will be welcome at this meeting, which will be in the nature of a public hearing, and their comments on the Division recommendations will receive careful consideration.

The recommendations approved by the Standards Committee will, in accordance with the Standards Committee regulations, be submitted for a letter ballot of the voting members of the Society before becoming official S.A.E. Standards and Recommended Practices.

AERONAUTICAL SAFETY CODE APPROVED

To Be Submitted by Aeronautic Division to the Standards Committee

In 1920, the Society accepted joint sponsorship with the Bureau of Standards for the purpose of organizing, under the rules of procedure of the American Engineering Standards Committee, a Sectional Committee to formulate a safety code covering aircraft construction and operation. The Sectional Committee organized was representative of the American aeronautic industry, over 17 organizations and societies being represented in addition to the Bureau of Standards and the Society.

In developing the code, each part was assigned to a Subcommittee, the parts being as follows:

Introductory Part—Scope and Nomenclature
Part 1—Airplane Structure, Design, Fabrication and Tests
Part 2—Powerplants, Design, Assembly and Tests
Part 3—Equipment, Maintenance and Operation of Airplanes
Part 4—Signals and Signaling Equipment
Part 5—Airdromes and Airways
Part 6—Traffic and Pilotage Rules
Part 7—Qualifications for Airmen
Part 8—Balloons
Part 9—Airships
Part 10—Parachutes

As each part was approved by a Subcommittee, it was printed in pamphlet form and over 900 copies were distributed among those interested to draw out criticism of the various requirements specified. An abstract of the entire Code was printed in the January issue of THE JOURNAL, p. 25.

At a meeting held on April 23 the Sectional Committee definitely adopted the Code with slight modifications as a result of criticisms received, and in accordance with the rules of procedure of the American Engineering Standards Committee it was submitted to the Bureau of Standards and the Society as joint sponsors. Reports of Sectional Committees, however, may be approved by the Society only by the same procedure as is followed in approving reports originating in Divisions of the Standards Committee. The Aeronautical Safety Code was therefore referred to the Aeronautic Division by the Council. As the Society representatives on the Sectional Committee are all members of the Aeronautic Division, the Aeronautic Division adopted the Sectional Committee report by letter ballot and the report will therefore be submitted at the Standards Committee Meeting at White Sulphur Springs for approval. Printed copies of the final Code will be available in preprint form at the Standards Committee Meeting.

The history of the Sectional Committee and the purpose of the Code are well outlined in the preface to the Code which follows herewith.

> The Aeronautical Safety Code is one of a series of safety codes formulated under the rules of procedure of the American Engineering Standards Committee. In 1920 the Society of Automotive Engineers and the Bureau of Standards were designated joint sponsors for the Code and in 1921 the Aeronautical Safety Code Sectional Committee was formed, all organizations that were interested in assisting in the development of the Code being represented thereon. A preliminary conference was held in the spring of 1921, and later in the same year the first meeting of the Sectional Committee was held at which its organization was effected. Subcommittees were then organized, the members of which were selected from all available sources as best qualified to deal with the individual topics.
>
> The draft of a Code that the Bureau of Standards had already prepared from such data as were then available was used by the several subcommittees as the foundation for their work and from it were developed the reports that were eventually submitted to the Sectional Committee. After several meetings and thorough consideration, the Sectional Committee made such revisions in the parts of the Code as seemed appropriate before they were printed for wider circulation and criticism.
>
> On April 23, 1925, a meeting of the Sectional Committee was held at which a large number of comments from various sources were considered and revisions made of the printed drafts. The Code was approved by the Sectional Committee as it was finally revised at this meeting.
>
> It is fully appreciated that aeronautics is in its infancy, that the art is rapidly developing, and that the time has not arrived for that degree of standardization which means crystallization into set forms of structures or of practices. It is not intended, therefore, that this Code should prevent development by prescribing too closely the acceptable methods of design, construction or operation. The intent has been rather to formulate canons of good practice which should be helpful in utilizing the experience of the past by indicating proper practice and eliminating that which has already been found unnecessarily hazardous. Inherent hazards are, themselves, sufficiently great and there is no warrant for unnecessarily subjecting pilots, passengers, manufacturers or the public to those hazards that can be eliminated by giving proper attention to the results of past experience and present

knowledge, and by conforming to a uniform set of traffic regulations. As this experience and knowledge accumulates, it is fully realized that this Code will need modification and that it can be improved. Revisions from time to time are consequently contemplated and will be made as frequently as may appear justifiable by future developments. In the meantime, it is hoped that the Code will prove a valuable guide to designers, constructors and operators of both aircraft and landing-fields, and will form a basis for the activities of any regulatory authorities that may be constituted. Commercial aviation should thereby be advanced.

It is hoped that those who acquire experience in applying the rules of this Code will feel free to consult the sponsors or the officers of the committee, pointing out any defects encountered and suggesting modifications as such experience may dictate. Cooperation of this kind will be heartily welcomed and will be helpful in perfecting future editions of this Code.

ARMY-NAVY STANDARDS APPROVED

Aeronautic Division Reviews Standards Adopted by Army and Navy Air Services

Owing to the fact that the Government is practically the only purchaser of aircraft, the Aeronautic Division has decided as a definite policy to propose as S.A.E. Recommended Practice such standards as are adopted by the Joint Army-Navy Air Service Conferences. At the first conference, held in Philadelphia on June 28, 1924, the Aeronautic Division was represented by E. W. Rounds, of the Wright Aeronautical Corporation. The purpose of the conferences is to eliminate the differences in the specifications and requirements for the standard parts of the Army Air Service and the Navy, and to adopt a uniform system of standards. The advantages of such a procedure will be self-evident to those who have in the past been obliged to carry duplicate stocks of so-called standard parts necessitated by slight differences in the Army and Navy requirements.

TURNBUCKLES

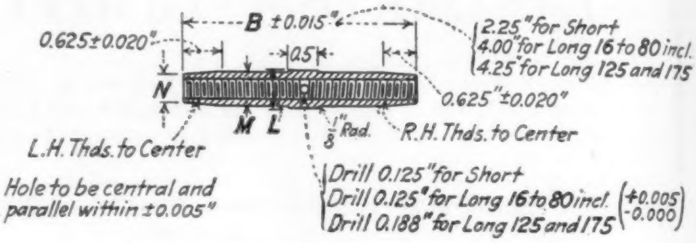


TABLE 1—THREAD AND BARREL DIMENSIONS

No.	Strength, Lb.	Threads[1]	Pitch-Diameter Limits[1]		L ±0.005	M ±0.005	N ±0.005
			Max.	Min.			
8S	800	6–40	0.1235	0.1218	0.250	0.219	0.188
16S or L	1,600	10–32	0.1716	0.1697	0.375	0.281	0.250
21S or L	2,100	12–28	0.1950	0.1928	0.375	0.328	0.281
32S or L	3,200	1/4–28	0.2290	0.2268	0.438	0.391	0.328
46S or L	4,600	5/16–24	0.2878	0.2854	0.500	0.438	0.406
61L	6,100	3/8–24	0.3503	0.3479	0.625	0.594	0.469
80L	8,000	3/8–24	0.3503	0.3479	0.625	0.594	0.469
125L	12,500	7/16–20	0.4076	0.4050	0.750	0.688	0.563
175L	17,500	1/2–20	0.4701	0.4675	0.875	0.813	0.625

[1] Screw-threads shall be in accordance with the Medium (Class 3) Fit for the Fine-Thread Series as specified in the American (National or S.A.E.) Standard for Screw-Threads, p. C1 of the S.A.E. HANDBOOK.

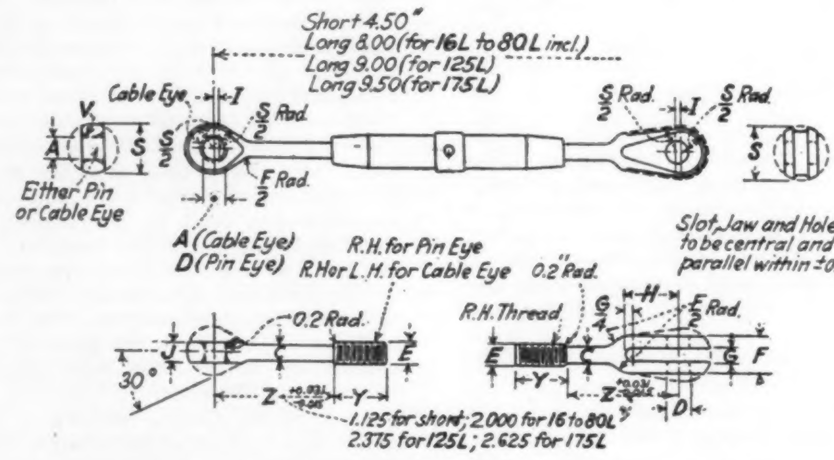


TABLE 2—DIMENSIONS OF CABLE-EYE, PIN-EYE AND FORK-ENDS

No.[1]	Strength, Lb.	EYE AND FORK-ENDS							EYE-END			FORK-END	
		C +0.006 −0.000	D +0.010 −0.000	E[2] Max.	F +0.010 −0.005	I +0.010 −0.000	S	Y ±0.047	A +0.010 −0.000	J	V	G +0.010 −0.000	H
8S	800	0.094	0.188	0.138	0.250	0.031	0.375	0.375	0.188	0.125	0.094	0.109	0.375
16S or L	1,600	0.133	0.188	0.190	0.313	0.031	0.500	0.500	0.219	0.188	0.172	0.150	0.469
21S or L	2,100	0.155	0.188	0.216	0.313	0.031	0.500	0.563	0.219	0.188	0.172	0.150	0.562
32S or L	3,200	0.189	0.250	0.250	0.438	0.047	0.625	0.625	0.281	0.219	0.203	0.203	0.625
46S or L	4,600	0.243	0.313	0.3125	0.500	0.047	0.688	0.750	0.313	0.281	0.250	0.203	0.625
61L	6,100	0.256	0.375	0.375	0.563	0.063	0.750	0.875	0.344	0.281	0.313	0.203	0.843
80L	8,000	0.306	0.375	0.375	0.563	0.063	0.875	0.875	0.375	0.328	0.375	0.266	0.875
125L	12,500	0.362	0.438	0.4375	0.719	0.078	1.063	1.000	0.469	0.375	0.453	0.344	1.000
175L	17,500	0.425	0.500	0.500	0.813	0.078	1.188	1.000	0.563	0.469	0.500	0.406	1.188

[1] This recommended practice is in agreement with Army-Navy Standards for Turnbuckles AN-44 to AN-50 adopted Nov. 1, 1924. The sizes are designated by the following key: *R*, right-hand thread; *L*, left-hand thread; *S*, short barrel; *L*, long barrel; 44, cable-eye; 45, fork; 46, pin-eye; 47, barrel; 48, turnbuckle assembly two cable-eyes; 49, turnbuckle assembly with cable-eye and fork; 50, turnbuckle assembly with cable-eye and pin-eye; *AN*, Army-Navy Standard. Thus *AN-44-46LL* indicates Army-Navy Standard long cable-eye with a left-hand thread for a cable strength of 4600 lb.

[2] Screw-threads shall be in accordance with the Medium (Class 3) Fit for the Fine-Thread Series as Specified in the American (National or S.A.E.) Standard for Screw-Threads, p. C1 of the S.A.E. HANDBOOK.

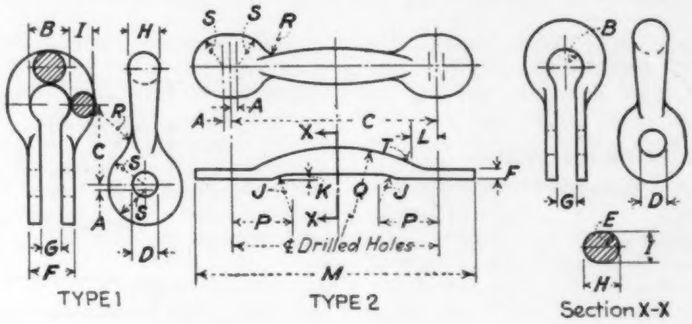


TABLE 3—DIMENSIONS OF CABLE SHACKLES

No.	Shackle and Cable Strength, Lb.	Shackle Type	*D* +0.010 −0.000	*G* +0.010 −0.000	*F*	*S*	*I*	*H*	*A*	*B*	*C*	*R*
8	800	1	0.188	0.109	0.250	0.250	0.172	0.172	0.031	0.250	0.563	0.375
16	1,600	1	0.188	0.150	0.313	0.250	0.172	0.172	0.031	0.250	0.563	0.375
21	2,100	1	0.188	0.150	0.313	0.281	0.172	0.172	0.031	0.250	0.563	0.375
32	3,200	1	0.250	0.203	0.438	0.313	0.219	0.250	0.031	0.375	0.750	0.438
46	4,600	1	0.313	0.203	0.500	0.375	0.219	0.281	0.063	0.438	0.813	0.500
61	6,100	1	0.375	0.203	0.563	0.375	0.281	0.313	0.063	0.500	0.875	0.500
80	8,000	2	0.375	0.266	0.148	0.406	0.375	0.438	0.063	0.219	2.750	0.406
125	12,500	2	0.438	0.360	0.179	0.531	0.469	0.594	0.094	0.313	4.000	0.750
175	17,500	2	0.500	0.406	0.203	0.625	0.563	0.688	0.125	0.313	4.250	0.500

Dimensions apply to shackles after zinc plating. Tolerances are plus and minus 0.010 in. unless otherwise specified. Drill holes shall be central and parallel to tolerances of plus and minus 0.005 in.

This recommended practice is in agreement with Army-Navy Standard *AN*-20 for Shackles adopted Nov. 1, 1924. The sizes are designated by "*AN*-20" and the number given in the above table, separated by a hyphen. For example, the *AN* Number for the largest shackles is *AN*-20-175.

No.	Shackle Type	*M*	*L*	*T*	*Q*	*P*	*J*	*K*	*E*
80	2	3.688	0.281	0.250	2.000	0.719	0.500	0.078	0.188
125	2	5.250	0.375	0.250	3.500	1.125	0.625	0.125	0.250
175	2	5.750	0.375	0.500	3.375	1.250	1.000	0.109	0.297

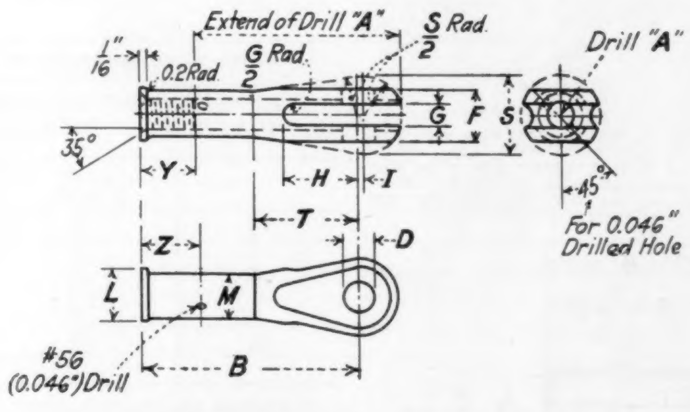


TABLE 4—DIMENSIONS OF RIGID TERMINALS

No.	Wire Strength, Lb.	*A* Thread	*A* Drill	Pitch Limits Diameter[2] Max.	Pitch Limits Diameter[2] Min.	*B* ±0.015	*D* +0.010 −0.000	*F* +0.010 −0.005	*G* +0.010 −0.000	*H*	*I*	*L*	*M* +0.010 −0.000	*S*	*T*	*Y* ±0.047	*Z*
10	1,000	6-40	0.147	0.1235	0.1218	1.313	0.188	0.250	0.109	0.375	0.031	0.313	0.250	0.375	0.625	0.250	0.313
21	2,100	10-32	0.199	0.1716	0.1697	1.532	0.188	0.313	0.150	0.469	0.031	0.375	0.281	0.500	0.719	0.313	0.375
34	3,400	1/4-28	0.261	0.2290	0.2268	1.813	0.250	0.438	0.203	0.625	0.047	0.438	0.375	0.625	0.875	0.438	0.500
46	4,600	5/16-24	0.323	0.2878	0.2854	1.875	0.313	0.500	0.203	0.625	0.047	0.500	0.438	0.688	0.875	0.563	0.625
61	6,100	5/16-24	0.323	0.2878	0.2854	2.000	0.375	0.563	0.203	0.843	0.063	0.500	0.453	0.750	1.000	0.563	0.625
80	8,000	3/8-24	0.386	0.3503	0.3479	2.250	0.375	0.563	0.266	0.875	0.063	0.563	0.547	0.875	1.125	0.688	0.750
115	11,500	7/16-20	0.453	0.4076	0.4050	2.500	0.438	0.719	0.344	1.000	0.078	0.687	0.625	1.063	1.250	0.750	0.813
155	15,500	1/2-20	0.516	0.4701	0.4675	2.813	0.500	0.813	0.406	1.188	0.078	0.750	0.703	1.188	1.438	0.875	0.938

Dimensions apply to shackles after zinc plating. Tolerances are plus and minus 0.010 in. unless otherwise specified. Drill holes shall be central and parallel to tolerances of plus and minus 0.005 in.

[1] This recommended practice is in agreement with Army-Navy Standard *AN*-30 for Rigid Terminals adopted Oct., 1924. The sizes are designated by "*AN*-30" and the numbers given in the above table separated by a hyphen. For example, the *AN* Number for the largest terminal is *AN*-30-155.

[2] Screw-threads shall be in accordance with the Medium (Class 3) Fit for the Fine-Thread Series as specified in the American (National or S.A.E.) Standard for Screw-Threads, p. C1 of the S.A.E. HANDBOOK.

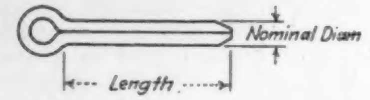


TABLE 5—DIMENSIONS OF BRASS COTTER-PINS

No.	Nom. Diam.	LENGTH											Approx. Weight Per Linear Inch, Pound
		2	3	4	5	6	7	8	10	12	14	16	
2	1/16	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	....	....	....	....	0.0011
3	3/32	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	....	....	....	....	0.0022
4	1/8	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2	....	....	....	0.0045
5	5/32	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2	....	....	....	0.0067
6	3/16	....	....	....	....	1 1/2	....	2	2 1/2	3	....	....	0.0101
8	1/4	....	....	....	....	....	....	2	2 1/2	3	3 1/2	4	0.0157

This recommended practice is in agreement with Army-Navy Standard *AN*-11 adopted Nov. 1, 1924. The sizes are designated by the Army and Navy by "*AN*-11," the cotter-pin size number given in the above table and the length designation, all separated by hyphens. For example, the *AN* Number for the largest cotter-pin would be *AN*-11-8-16.

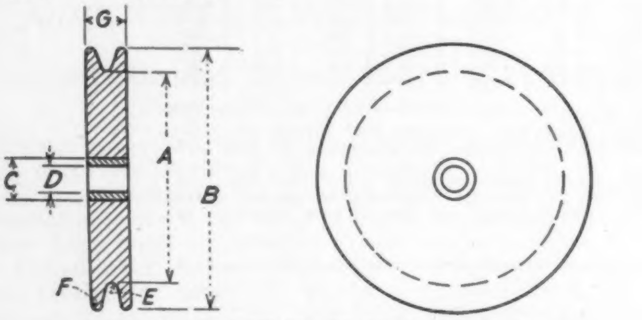


TABLE 6—DIMENSIONS OF CABLE PULLEYS

No.[1]	Cable Size	*A*	*B*	*C*	*D* ±0.002	*E*	*F*	*G* ±0.015
1	1/16, 3/32	7/8	1 1/4	3/8	0.253	3/64	1/32	17/64
2	1/16, 3/32	2	2 1/2	3/8	0.253	3/64	1/32	17/64
3	1/8, 5/32, 3/16	1 3/8	2	1/2	0.378	7/64	3/64	7/16
4	1/8, 5/32, 3/16	2 7/8	3 1/2	1/2	0.378	7/64	3/64	7/16

Tolerances are plus and minus 0.010 in. unless otherwise specified.

[1] This recommended practice is in agreement with Army-Navy Standard *AN*-21 for Shackles adopted Nov. 1, 1924. The sizes are designated by "*AN*-21" and the numbers given in the above table, separated by a hyphen. For example, the *AN* Number for the largest pulley is *AN*-21-4.

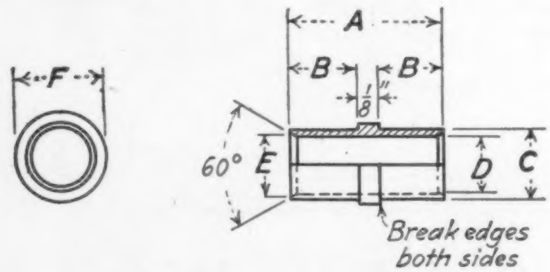


TABLE 7—DIMENSIONS OF HOSE LINERS

No.	Tube Size	*A*	*B*	*C* ±0.002	*D*	*E*	*F*
4	1/4x0.032	3/4	5/16	0.176	0.140	..	1/4
6	3/8x0.032	3/4	5/16	0.300	0.238	..	3/8
8	1/2x0.032	3/4	5/16	0.419	23/64	..	1/2
10	5/8x0.032	1/8	1/2	0.543	31/64	1/2	5/8
12	3/4x0.049	1/8	1/2	0.640	37/64	39/64	3/4

Tolerances are plus or minus 0.010 in. unless otherwise specified.

This recommended practice is in agreement with Army-Navy Standard *AN*-31 for Hose Liners adopted Oct. 14, 1924. The sizes are designated by the Army and Navy by "*AN*-31" followed by the numbers given in the above table, separated by a hyphen. For example, the *AN* Number for the largest hose liner is *AN*-31-12.

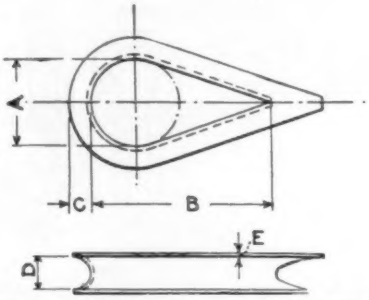


TABLE 8—DIMENSIONS OF CABLE THIMBLES

Number[1]	*A*	*B*	*C*	*D*	*E*		Cable Diam.[2]	Approx. Weight,[2] Lb.
					Nom.	Tol.		
3	0.35	0.70	0.07	0.09	0.032	±0.003	1/16, 5/64, 3/32	0.0030
4	0.35	0.70	0.07	0.13	0.032	±0.003	7/64, 1/8	0.0043
5	0.40	0.80	0.10	0.17	0.032	±0.003	5/32	0.0065
6	0.50	1.00	0.135	0.21	0.032	±0.003	3/16	0.0090
7	0.60	1.20	0.15	0.24	0.032	±0.003	7/32	0.0143
8	0.70	1.40	0.17	0.25	0.032	±0.003	1/4	0.0163
9	0.80	1.60	0.198	0.30	0.040	±0.004	9/32	0.0263
10	0.90	1.80	0.21	0.33	0.040	±0.004	5/16	0.0295
12	1.00	2.00	0.26	0.39	0.060	±0.004	3/8	0.0770

Dimensions apply to timbles after zinc-plating. Tolerances are plus or minus 1/64 in. unless otherwise specified.

[1] This recommended practice is in agreement with Army-Navy Standard AN19 for Thimbles adopted Oct. 14, 1924. The sizes are designated by "AN19" and the numbers given in the above table separated by a hyphen. For example, the AN Number for the largest thimble is AN19-12.

[2] General information only.

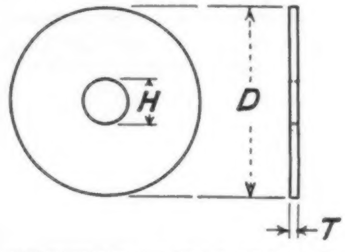


TABLE 9—DIMENSIONS OF STEEL WASHERS FOR WOOD

No.	*H*	*D*	*T*
3	No. 10 (0.1935)	7/8	1/16
4	17/64	1 1/8	1/16
5	21/64	1 3/8	1/16
6	25/64	1 5/8	1/16
7	29/64	1 13/16	1/10
8	33/64	2	1/10
9	37/64	2 3/16	1/8
10	41/64	2 3/8	1/8

Tolerances are plus and minus 0.010 in.

This recommended practice is in agreement with Army-Navy Standard *AN*-22 for Washers adopted Nov. 1, 1924. The sizes are designated by "*AN*-22" and the numbers given in the above table, separated by a hyphen. For example the *AN* number for the largest size would be *AN*-22-10.

It is not intended that the new AN Standards shall render the existing Army and Navy Standards immediately obsolete. In practically all cases the old and the new standards are interchangeable, or the old can be readily converted to the new by minor modification. When it is impracticable to make the conversion, the Army and Navy will accept parts conforming to the old standards until the supply on hand is exhausted. Manufacturers of standard parts will receive waivers on orders calling for the new standards so that they may deliver material conforming to the old standards when it is shown that the material was manufactured before the promulgation of the AN Standards. It is desired, however, that new parts, made after such promulgation, be in accordance with the AN Standards.

The Aeronautic Division has reviewed to date the AN

Standards on Turnbuckles, Hose-Liners, Washers, Cotter-Pins, Shackles, Thimbles, Terminals and Pulleys. The standards for turnbuckles and thimbles are, except for unimportant differences, the same as the present S.A.E. Recommended Practices for Turnbuckles and Thimbles, pp. C79 and C73 of the S.A.E. HANDBOOK respectively. In submitting these standards for adoption as S.A.E. Recommended Practice, it is understood that the present S.A.E. Recommended Practices shall be superseded by the present recommendations.

The AN Standards approved by the Aeronautic Division are given herewith practically in the form that they will appear, if adopted, in the S.A.E. HANDBOOK.

TRACTOR TESTING FORMS RECOMMENDED

Report by O. W. Sjogren Approved by Agricultural Power Equipment Division

Although the Agricultural Power Equipment Division has not held a meeting since April, 1924, Division action has been taken by letter ballot on the report of the Subdivision on Tractor Rating Code and Testing Forms submitted by Prof. O. W. Sjogren, chairman of the Subdivision. The report is given hereinafter. The complete personnel of the Subdivision is

O. W. Sjogren, *Chairman*	University of Nebraska
C. E. Frudden	Buda Co.
G. W. McCuen	Ohio State University
J. F. Max Patitz	Allis-Chalmers Mfg. Co.
A. W. Scarratt	Minneapolis Steel & Machinery Co.
G. A. Young	Purdue University
O. B. Zimmerman	International Harvester Co.

In view of the fact that Professor Sjogren is also chairman of a committee appointed by the American Society of Agricultural Engineers to consider this subject, the same report has been submitted to both organizations.

In the correction formula 70 instead of 60 deg. fahr. and 28.6 instead of 30.0 in. of mercury are used, since these figures conform more nearly to the conditions found throughout the tractor region of the Middle West. If a rating is based on corrections made at 30 in. of mercury and 60 deg. fahr., it may be higher than the power actually delivered in the test.

When finally approved by the Society, the testing forms will be printed on 8½ x 11-in. sheets from which blueprints may be made, the forms being similar to the present S.A.E. Engine Testing Forms.

The report will be submitted for adoption as S.A.E. Recommended Practice at the Standards Committee at White Sulphur Springs.

TRACTOR RATING CODE

TRACTOR RATING SPECIFICATIONS

Belt Rating.—The belt-horsepower rating of the tractor shall not exceed 90 per cent of the maximum load which the engine will *maintain by belt at the brake or dynamometer* for 2 hr. at rated engine speed, the test to be carried out as specified herein.

Drawbar Rating.—The drawbar rating of the tractor shall not exceed 80 per cent of the maximum drawbar horsepower developed at a rate of travel recommended for the ordinary operations for the tractor, under conditions of testing as specified herein.

TESTING PROCEDURE

Nature of Tests.—The following rating tests are to be conducted in the order given on three or more tractors picked at random from factory stock by the engineer or engineers conducting the test. The averages of all tests are to be used in determining the results.

Limbering-Up Run.—Before a test is undertaken it is important that the tractor shall have been in operation for a sufficient length of time to attain proper operating-conditions throughout so that the results of the test shall express the true working performance. The tractor or trac-

NAME, MODEL AND RATING ____
ENGINE NO. ____ CHASSIS NO. ____
ENGINE NAME ____ RATED R.P.M. ____
NO. CYLS. ____ BORE ____ IN. STROKE ____ IN. DISPL. (D) ____ CU. IN.
CARBURETER SYSTEM ____
IGNITION SYSTEM ____

FUEL ____ SP. GR. ____ AT 60° F.
DYNAMOMETER ____ ARM (R) ____ FT.
ROOM TEMP. ____ °F. BAR ____ IN. HG. HUMIDITY ____ %
ENGINE PULLEY DIA. ____ IN. CIR. (C_f) ____ FT.
BRAKE PULLEY DIA. ____ IN. CIR. (B_f) ____ FT.
BELT USED ____
PLACE OF TEST ____ DATE ____
OBSERVERS ____

RUN NUMBER	SYMBOL	FORMULA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	AVER.
TIME STARTED																	
TIME OF RUN-MIN.	t																
ENG. COUNTER START	C_o																
ENG. COUNTER STOP	C_t																
AV. ENG. R.P.M.	N	$\frac{C_o - C_t}{t}$															
BRAKE COUNTER START	B_o																
BRAKE COUNTER STOP	B_t																
AV. BRAKE R.P.M.	N_1	$\frac{B_o - B_t}{t}$															
ENG. PULLEY SUR. SPEED	S_1	$C_f N$															
BRAKE PULLEY SUR. SPEED	S_2	$B_f N_1$															
BELT SLIP %	S	$\frac{S_1 - S_2}{S_1}$															
BRAKE LOAD AT ARM R	P																
TORQUE LB. FT.	T																
BRAKE HORSEPOWER	B.HP.	$\frac{PRN}{5252.1}$															
WT. FUEL START LB.	W_o																
WT. FUEL END LB.	W_1																
FUEL USED LB. IN TIME t	W	$W_o - W_1$															
LB. FUEL PER B.HP. HR.	F	$\frac{60W}{t \times B.HP.}$															
AIR TEMP TO CARB. F°																	
TEMP. JACKET WATER IN F°																	
TEMP. JACKET WATER OUT F°																	

BELT-HORSEPOWER LOG-SHEET

NAME, MODEL AND RATING ______
ENGINE NO. ______ CHASSIS NO. ______
ENGINE NAME ______ RATED R.P.M. ______
NO. CYLS. ____ BORE __ IN STROKE __ IN DISPL. (D) ____ CU. IN.
CARBURETER SYSTEM ______
IGNITION SYSTEM ______

FUEL ______ SP. GR. ______ AT 60° F.
DYNAMOMETER ______
AIR TEMP. ____ ° F. BAR ____ IN. HG. HUMIDITY ____ %
TYPE LUGS ____ SIZE ____ DRIVE WHEELS DIA. ____ IN.
*DISTANCE PER REV. OF DRIVE WHEELS ON TEST GROUND (d_1) __ FT.
KIND AND CONDITION OF SOIL ______ DIST. OF RUN (d_2) __ FT.
PLACE OF TEST ______ DATE ______
OBSERVERS ______

RUN NUMBER	SYMBOL	FORMULA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	AVER.
TIME FOR RUN MIN.	t																
ENGINE R.P.M.	N																
L. WHEEL COUNT. START	C_{L_1}																
L. WHEEL COUNT. STOP	C_{L_2}																
NO. REVS. L. WHEEL	R_L	$C_{L_2}-C_{L_1}$															
R. WHEEL COUNT. START	C_{R_1}																
R. WHEEL COUNT. STOP	C_{R_2}																
NO. REVS. R. WHEEL	R_R	$C_{R_2}-C_{R_1}$															
AV. NO. REVS. R. AND L. WHEELS	R	$\frac{R_L+R_R}{2}$															
DISTANCE BY DRIVERS	D	d_1R															
WHEEL SLIPPAGE %	S_W	$\frac{D-d_2}{D}$															
AV. DRAFT LB.	P																
SPEED FT. PER MIN.	F	d_2/t															
SPEED MI. PER HR.	M	$f/88$															
DRAWBAR HORSEPOWER	D.B. HP.	$\frac{P \times f}{33000}$															
TEMP ATOM F°	F_A																
TEMP. JACKET WATER OUT	F_W																

* SEE CODE FOR METHOD

DRAWBAR-HORSEPOWER LOG-SHEET

tors to be tested shall therefore be submitted to "limbering-up" runs on the drawbar of 12-hr. or more duration. Drawbar loads of approximately one-third, two-thirds and full load shall be pulled by the tractor during the runs, each load being drawn for approximately an equal length of time, the lighter loads being used first.

Maximum Brake-Horsepower Test.—The tractor engine is to be tested in the belt with the governor set to give full opening of governor valve, and the carbureter set to give maximum power at rated engine crankshaft speed. (The rated speed is that which the manufacturer recommends for the engine under normal load.) The test shall begin after the temperature of the cooling fluid and other operating conditions have become practically constant. The duration of this test shall be 2 hr. of continuous running with no change in engine adjustments. If the speed should change sufficiently during the test to indicate that the operating conditions had not become constant when the test was started, the test will be repeated with the necessary change in load as measured in pounds on dynamometer or brake scale. Minor changes in load are to be made to maintain the rated speed and the average load and average speed for the period shall be used in computing the horsepower. All belt-horsepower tests must be made with an electric dynamometer, or with an accurately tested prony-brake or other accurate power-measuring device. Correction shall be made for temperature and altitude effect on horsepower output. Standard conditions of barometric pressure of 28.6 in. of mercury and a temperature of 70 deg. fahr. or 530 deg. absolute temperature shall be used.

The following correction formula shall be used:

$$Hp_c = Hp_o \times (P_s/P_o) \times \sqrt{(T_o/T_s)}$$

where

Hp_c = corrected brake-horsepower
Hp_o = observed brake-horsepower
P_o = observed barometric pressure in inches of mercury
P_s = standard barometric pressure in inches of mercury
T_o = observed absolute temperature in degrees fahrenheit
T_s = standard absolute temperature in degrees fahrenheit

Maximum Drawbar-Horsepower Test.—After the tractor has attained proper working conditions it shall be subjected to a series of drawbar tests, preferably on level ground, and of such a nature that it will provide a firm footing and offer tractive resistance simulating that of grain stubble ground in good plowing condition. The loads shall be successively increased or decreased to a point where the tractor can sustain a constant pull for a distance of not less than 1000 ft. with the average engine-speed maintained within 5 per cent of its rated full-load speed and a wheel slippage of not more than *10 per cent*. The wheel slippage to be obtained as follows: The tractor shall be driven without any drawbar load for a distance sufficient to give *10 revolutions* of the drive wheels. This distance shall be accurately measured and used as the basis for computing wheel slippage. The number of revolutions of all drivers shall be counted for the entire distance through which the load is pulled. The drawbar pull shall be measured by an accurately calibrated draft-dynamometer or draft measuring-device placed between the tractor and the load. The actual distance traveled shall be used in calculating the horsepower, no allowance being made for wheel slippage. During this test

the tractor shall be run in the gear recommended for plowing under favorable conditions.

Fuels.—These tests will be made on the lowest commercially available grade of fuel which the manufacturer recommends for the tractor.

Lubricants.—The lubricants used in these tests shall be such as are regularly recommended by the manufacturer for use with the tractor.

Belts.—The belt or belts used in these tests shall be such as the manufacturer recommends for use with the tractor in ordinary operation. No allowance will be made for belt losses.

INSULATED CABLE STANDARD REVISED

Immediate Action on Corona Test Not Expected, Owing to Research Involved

The present S.A.E. Standard for Insulated Cable, p. B33 of the S.A.E. HANDBOOK, has been carefully reviewed by the Subdivision on Insulated Cable, of which F. W. Andrew is chairman. At a meeting held in November, 1924, several revisions were approved and subsequently these were confirmed by the Electrical Equipment Division. These revisions will be submitted to the Standards Committee for adoption, although the Subcommittee on Tests, of which D. N. Pierson, of Dodge Bros. is chairman, is still working on the development of a satisfactory corona test for high-tension cable. Tests developed to date are not satisfactory, results obtained for wire from the same sample not being consistent. The industry as a whole is not familiar with the corona test which, as the name implies, is a break-down test of wire when wound around a mandrel so that ozone is formed.

The revisions in the present specifications as proposed by the Division are as follows:

PROPOSED REVISIONS OF THE S.A.E. STANDARD FOR INSULATED CABLE

I. General Specifications.—Insert the following footnote in Table 1 for Armor Thickness and Width Dimensions:

The small size of armor shall be used on No. 10 and smaller, and the large armor on wire heavier than No. 10.

II. Tests.—Insert the following as the last paragraph for Physical Tests and the Oil Test for Braided Cables:

The following may be used as an alternative to the above test: Six samples of each size of cable, 10 in. long, shall be suspended from a rack in a vertical position in a constant-temperature oven and shall be subjected continuously to a dry heat of 158 deg. fahr. for a period of 96 hr. The samples shall then be removed and allowed to hang in the air at room temperature for 24 hr., after which they shall be bent tightly around a mandrel, using a ½-in. mandrel for No. 10 A.w.g. cable and smaller and a 1½-in. mandrel for cable over No. 10 A.w.g. Neither the insulation nor covering of the samples shall crack when subjected to this test.

III. Specifications for High-Tension (Secondary) Ignition Cables.—Revise the second paragraph to read:

High-tension (secondary) ignition cables shall be plain rubber-covered, varnished cambric taped, single braided or double braided. Weatherproof braid shall not be used on this type of cable.

Insert the following as the third paragraph:

When varnished cambric strips are used, there shall be an overlap of 25 per cent when measured normally to the width of the strip.

V. Specifications for Rubber-Covered Lighting and Starting Cables.—Insert the following footnote under Table 2:

The total circular-mil area of any given strand shall not vary more than 2½ per cent from the nominal circular-mil area of that strand.

In Table 4, for the recommended stranding and dimensions of lighting and starting cable, make the following revisions:

Omit Cable No. 2.

Include for Cable No. 4 a stranding of 49 wires of No. 21 gage.

Specify the following actual circular-mils:

Cable No. 16—2,416; 2,556; 2,408
14—3,825; 4,154
12—6,087; 6,606
10—9,678; 9,866
8—15,389; 15,954
4—39,639; 39,199
1—81,613; 85,468
0—102,866; 107,726
00—129,723; 135,851; 131,935

Change the "Minimum Thickness of Rubber Wall" to "Thickness of Rubber Wall" with tolerances of plus and minus 0.005 in.

Specify the thickness of rubber wall for the No. 16 cable as 0.027 in. instead of 0.022 in.

Include the following footnote:

The total circular-mil area of any strand shall not vary more than 2½ per cent from the actual figures given.

Change the note at the end of Section V to read:

Note: Lighting and starting cables shall be rubber-covered, varnished cambric taped, single braided, or double braided.

VI. Specifications for Varnished Cambric Insulation Lighting and Starting Cables.—Change the second paragraph to read:

Lighting and starting cables of this class shall have two or more strips of overlapping varnished cambric-strip tape. Alternate layers shall be laid in opposite directions. The overlap shall be not less than 25 per cent of the width of the cambric strip measured normally to the edge of the strip.

VII. Specifications for Armored Lighting and Starting Cables.—Change the second paragraph to read:

Lighting and starting cables of this class shall have two or more strips of overlapping varnished cambric strips. Alternate layers shall be laid in opposite directions. The overlap shall be not less than 25 per cent of the width of the cambric strip measured normally to the edge of the strip.

CLUTCH-BEARING STANDARD CANCELLED

In 1921 a report of the Ball and Roller Bearings Division covering the bore and width of clutch-release type thrust ball-bearings was adopted as S.A.E. Recommended Practice. As this recommended practice had not been followed by the industry, a Subdivision was recently appointed to review the possibilities of developing a standard for clutch-release type of thrust ball-bearings that would be actually used in future production. The personnel of the Subdivision was

J. H. Baninger, *Chairman*	Gurney Ball Bearing Co.
F. Beemer	Nice Ball Bearing Co.
D. F. Chambers	Bearings Co. of America
T. C. Delaval-Crow	New Departure Mfg. Co.
D. E. Gamble	Borg & Beck Co.

Meetings of the Subdivision were held on April 8 and May 19. In accordance with the action taken at the first meeting, information was obtained from the various bearing manufacturers showing the exact dimensions used by each manufacturer for the clutch-release type of thrust ball-bearings produced in greatest quantity and considered as sizes that should be continued as standard. This survey was analyzed at the May meeting and, although it was found that many sizes used by different car manufacturers were prac-

tically the same in bore and width, variations in the outside diameter and in the band or retainer made standardization practically impossible.

In studying present practice, it was found that many non-standard angular-contact bearings were used for the clutch-release. It was the consensus of opinion that, when this type of bearing is used, the boundary dimensions should conform to the present S.A.E. Standard for Angular-Contact Bearings.

The Subdivision therefore proposed that the present S.A.E. Recommended Practice for Clutch-Release-Type Thrust Ball-Bearings, published on p. C34 of the S.A.E. HANDBOOK be cancelled. This recommendation was confirmed by letter ballot by the Ball and Roller Bearings Division.

POPPET-VALVE STANDARD REVISED

In the last few years the Engine Division has recognized that the present S.A.E. Standard for Poppet Valves, p. A4 of the S.A.E. HANDBOOK, is not in accord with current practice, owing to developments since the standard was originally adopted in 1917. A Subdivision was therefore appointed to review current practice and to draft a preliminary report. This Subdivision consisted of J. B. Fisher, of the Waukesha Motor Co., chairman; L. F. Burger, of the International Harvester Co.; Robert Jardine, of the Rich Tool Co.; and F. H. White, of the Toledo Steel Products Co.

At the April Meeting of the Engine Division a report submitted by Mr. Fisher was approved by the Subdivision. This report was printed in full in the May issue of THE JOURNAL, p. 495. Since the publication of the report in the May JOURNAL, the following needed corrections have been noted.

Radii for the curvature of the crown of the valve-head shall be as follows:

Nominal Size, In.	*Radius, In.*
1 to 1⅜	5
1½ to 1⅞	6
2 to 2¼	7
2⅜ to 2⅝	8
2¾ to 3	9

The footnote for the concentricity of the valve-seat should read as follows:

Concentricity.—The concentricity of the valve-seat with the ground stem shall be inspected by rolling the valve in a V-block, the length of which shall be the length of the ground stem, and which shall be relieved at the center, this relief extending to within ½ in. of each end. The valves shall be held lengthwise by a ball bearing against the center of the tip of the stem. The indicator pin shall bear against the valve-seat at an angle of 90 deg.

The footnote with reference to the hardening of the valve-stem tips should read, "so as to prevent undue breakage after hardening," not "so as to prevent undue breakage in hardening."

As the report has been referred to engine manufacturers and automobile manufacturers making their own engines and has met with general favor, it will be submitted to the Standards Committee for approval as a revision and extension of the present S.A.E. Standard.

LIMITS FOR CLUTCH DISCS RECOMMENDED

The present S.A.E. Standard for Flywheel Housings specifies that the limits for the counterbore in the flywheel intended to receive the clutch driving-member shall be 11.500 to 11.503 in. At the April meeting of the Engine Division a report was submitted covering present practice for the dimensions of the counterbore, as well as for the outside diameter of the clutch driving-member, it having been considered that closer limits for the flywheel counterbore should be specified. The information showed, however, that it is not practicable to specify closer limits, but that limits of 11.497 to 11.499 in. for the clutch driving disc should be recommended as desirable dimensions for this mating part. These tolerances permit a spread of from 0.001 to 0.006 in. between the flywheel counterbore and the outside diameter of the clutch disc, which is considered in line with good engineering practice.

The Engine Division has therefore recommended that the present S.A.E. Standard for Flywheels and Flywheel Housings, p. A1 of the S.A.E. HANDBOOK, be revised to specify limits of 11.497 to 11.499 in. for the clutch driving-member.

CHANGE IN THROTTLE-LEVER THREAD

The present S.A.E. Standard for Carbureter Throttle Levers, p. J3 of the S.A.E. HANDBOOK, specifies that the rod-ends from the ½ to the 1-in. nominal carbureter size shall have a 3/16 in.-32 thread. The S.A.E. Standard for Screw-Threads specifies numbered sizes below ¼ in., the standard thread corresponding to 3/16 in.-32 being No. 10-32.

In order that the standard for Carbureter Throttle Levers may be consistent with the Screw-Thread Standard and practice in the industry, the Engine Division recommends that a No. 10-32 thread be specified instead of 3/16 in.-32.

PISTON-PIN DIAMETERS TO BE LIMITED

Engine Division Recommends Even 1/16-In. Diameters with 0.005 and 0.010-In. Oversizes

At a conference held at the City of Washington in December, 1924, on the simplification of piston-rings, the Society was asked to undertake the standardization of piston-pins and piston-pin bushings. It was thought that an economic saving should result from such standardization. The Council of the Society therefore referred the request to the Engine Division for comment. At a meeting on April 14 the Engine Division proposed for adoption as S.A.E. Recommended Practice that all piston-pins shall be finished to even 1/16-in. diameters, with oversizes of 0.005 and 0.010 in.

It is believed that, if this standard shall be generally adopted, it will result in reducing the larger number of reamers that it is now necessary to carry in stock. The standardization of actual diameters, lengths and bearing surfaces is not considered desirable, as they depend too largely on individual engine design.

FOUR MOLYBDENUM STEELS PROPOSED

Iron and Steel Division Recommends Compositions Using 4000-Series Numbers

When the present S.A.E. Iron and Steel Specifications were revised in July, 1923, it was not possible to recommend definite compositions for molybdenum steels as the members of the Division and the industry in general did not have sufficient experience on which to base any final conclusions. At the March meeting of the Iron and Steel Division, the Subdivision, of which M. H. Schmidt was chairman, submitted for Division approval a report that had been drawn up by J. D. Cutter of the Climax Molybdenum Co. This report was based on a survey of the molybdenum steel compositions that were being used by the industry. The report, revised in some particulars, was approved by the Iron and Steel Division for adoption as S.A.E. Recom-

MOLYBDENUM STEELS SPECIFICATIONS RECOMMENDED

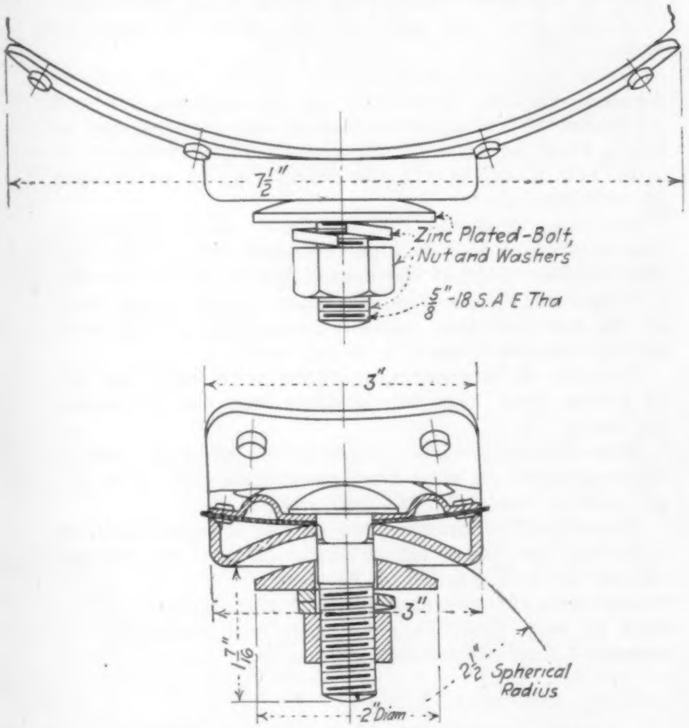
S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Maximum	Sulphur, Maximum	Chromium Range	Nickel Range	Molybdenum Range
4130	0.25–0.35	0.40–0.70	0.04	0.045	0.50–0.80	....	0.15–0.25
4140	0.35–0.45	0.40–0.70	0.04	0.045	0.80–1.10	....	0.15–0.25
4150	0.45–0.55	0.40–0.70	0.04	0.045	0.80–1.10	....	0.15–0.25
4615	0.10–0.20	0.30–0.50	0.04	0.045	....	1.25–1.75	0.20–0.30

mended Practice only and is given herewith. It is understood that the adoption of the compositions as S.A.E. Standard will be considered in one year, adoption as standard to be dependent on the extent which the composition shall have been adopted in actual practice.

MOTORCOACH LAMP MOUNTING

Heavier Type of Universal Mounting Needed for Motorcoaches Than for Passenger Cars

At the meeting of the Lighting Division held on May 15 it was brought out that a heavier type of universal mounting for head-lamps is needed for motorcoaches than the present S.A.E. Recommended Practice for passenger-car head-lamps, given on p. B1a of the S.A.E. HANDBOOK. A type of mounting that has been used in practice with good results was recommended by Chairman C. A. Michel; this mounting, shown in the accompanying drawing, being similar to the present passenger-car mounting with the ex-



PROPOSED UNIVERSAL MOUNTING FOR HEAD-LAMPS ON MOTORCOACHES

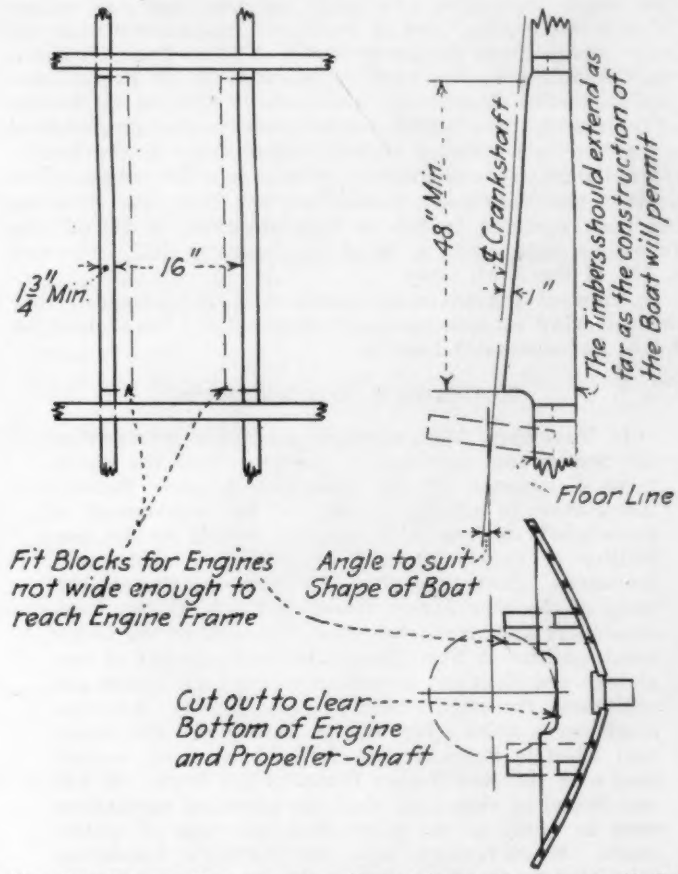
ception that the bearing surface, bolt and bearing washer are larger, the washer being turned from bar stock. The mounting was approved by the Lighting Division for adoption as S.A.E. Recommended Practice and will be submitted for action at the Standards Committee Meeting on June 18.

ENGINE BED-TIMBERS ADOPTED

Recommendation Provides Interchangeability of Small Motorboat Engines

Since the Motorboat Division was organized in 1918, it has been appreciated that engines for small motorboats should be interchangeable. This does not mean necessarily that the engines should be made to standard mounting dimensions, for, if all boats using engines in this class were designed with the bed timbers spaced a standard distance apart, engines could be mounted on the bed timbers or on blocks bolted to them. Such standardization would make it unnecessary for future boat-owners to pay excessive charges for rebuilding bed timbers when having new engines installed, as is generally the case under present conditions.

In considering this subject a comprehensive survey was



BED TIMBERS FOR ENGINES WITH PISTON-DISPLACEMENTS OF 75 CU. IN. OR LESS PER CYLINDER

As the Construction of the Engine-Bed Depends to a Large Extent upon Each Particular Application, the Construction Shown Is Not Intended as Recommended Practice but Merely To Illustrate the Dimensions Recommended

made of the installation diagrams for the various makes of engine, the number of cylinders, the bore and stroke, the displacement, the nominal speed, the horsepower at the nominal speed and the diameter of the flywheel. The preliminary report was based on this information and was submitted to over 300 boat builders for criticism. The original report covered two widths of bed timbers; 16 in. for engines under 25 hp. and 19 in. for engines of from 26 to 100 hp. As the criticism received involved the bed-timber widths for the larger engines and as the great majority of motorboat engines are of 25 hp. or less, the Division limited its recommendation to the smaller classification, with the understanding that a standard for the larger engines would be recommended at a later date.

As the size of the engine, and consequently the amount of space needed for the mounting, are dependent more on the piston displacement per cylinder than upon the horsepower, the 16-in. bed-timber spacing was limited to engines of less than 75-cu. in. piston displacement per cylinder, which corresponds approximately to 25 hp. The Division records show that over 90 per cent of the engines sold for motorboats come within this classification. The Division report, which will be submitted for approval as recommended practice at the Standards Committee Meeting at White Sulphur Springs, is given in the accompanying illustration.

MOTORCOACH SPECIFICATIONS PROPOSED

Intended as Guide for Motorcoach Builders and State Regulatory Officials

The S.A.E. Motorcoach Division, which was originally appointed in 1923 as a Special Committee, has devoted its work in the past largely to the development of specifications

that might well serve as a basis for municipal regulations. In this work close contact has been maintained with the New Jersey State Board of Public Utility Commissioners, the Committee having been represented at all public hearings held. The Committee's work largely affected the rulings of the Board, many objectionable requirements being omitted or revised in a manner entirely satisfactory to the Motorcoach Committee and builders of this type of vehicle. The work of the Motorcoach Committee, and later, the Division, has been reported in full in THE JOURNAL, p. 492 of the December, 1924, issue, p. 28 of the January, 1925, issue and p. 409 of the April issue.

In view of the Division's work, it is recommended that the following introduction and specifications be adopted as S.A.E. Recommended Practice.

MOTORCOACH SPECIFICATIONS

In November, 1923, a small committee representing the Society was appointed to cooperate with the Equipment Committee of the American Electric Railway Association in making a study of the development of motorcoach designs with especial regard to the possibility of developing and promulgating motorcoach standards. Soon thereafter the transportation department of the New Jersey Board of Public Utility Commissioners and representatives of several of the larger municipalities in New Jersey drafted a number of regulatory specifications to govern motorcoach design and equipment for enforcement in New Jersey. Arrangements were made whereby the Society and the American Electric Railway Association committees cooperated with the New Jersey Board in this work. It was understood at that time that the proposed regulations were to apply to the single-deck city-type of motorcoach. In November, 1924, the Society's Committee submitted to the New Jersey Board recommendations covering specifications considered desirable as a basis for municipal regulations. However, after the final public hearing held by the Board at Trenton, on Nov. 25, it was ruled that the regulations would apply to all motorcoaches coming within the jurisdiction of the Board of Public Utility Commissioners in New Jersey. On Dec. 29, 1924, the final regulations, which include a number of the Committee's recommendations, were issued to apply to all motorcoaches placed in operation thereafter in New Jersey.

Early in 1925 the Motorcoach Committee was reorganized as the Motorcoach Division of the Standards Committee. The Division believes that the following general specifications, necessarily broad in scope, will serve as an effective guide to State officials in formulating regulations that will be sufficiently uniform in their requirements to place no serious handicap on motorcoach manufacturers or operators, and not restrict proper development of this type of vehicle.

Width of Door.—The entrance and exit door of motorcoaches shall have a minimum clear-width of 24 in.

Emergency Door.—Motorcoaches shall be provided with an emergency door located in the side or in the rear. The door shall have a minimum clear-width of 18 in.

Visibility.—The construction of the front end of motorcoach bodies shall be such as to afford the driver an unobstructed view to the right and the left. The construction of the window at the left of the driver shall be such that it may be readily opened for hand-signaling purposes.

Handles.—Rails or grab-handles must be located inside the vestibule and shall be securely fastened.

Ventilators.—Motorcoaches shall be equipped with ventilators of a suitable type to assure proper ventilation.

Heating.—An adequate heating system shall be installed when required.

Gasoline Tanks.—When the gasoline tank is installed inside of the body, it shall be filled, vented and drained from the outside of the body.

Mirrors.—All motorcoaches shall be provided with an inside mirror.

Foot-Boards.—The front foot-boards shall be constructed of fireproof material.

Inside Lights.—The interior lighting shall be at least 5 rated cp. per seat passenger capacity.

Wiring.—The minimum size of wire from the battery and the generator to the point of lighting distribution shall be No. 8 A.w.g. stranded. For the interior distribution system of lighting, two lamp circuits in parallel are recommended, for which the minimum size of wire shall be No. 12 A.w.g. stranded, or the equivalent. When more than two lamp circuits are used, the minimum wire-size shall be No. 14 A.w.g. stranded, or the equivalent. All terminal connections shall be soldered and all splices shall be soldered and taped.

Passenger Signal-System.—Suitable signaling devices shall be installed within easy reach of all passengers.

Stop-Lights.—All motorcoaches shall be equipped with a stop-light.

Destination and Route Signs.—A route sign shall be located over the windshield on all motorcoaches and so placed and illuminated that it may be read day or night from at least 70 ft. ahead of the vehicle. It must not interfere with the driver's vision or produce an annoying glare.

Overhang of Body.—The maximum rear overhang of the motorcoach body beyond the center-line of the rear axle shall be 7/24 of the overall length of the chassis.

Height of Floor.—The maximum height of the floor at the entrance door, measured from the ground level without pay-load, shall be 35 in.

Brakes.—Motorcoaches equipped with only one set of brakes shall have two distinct methods of operating them.

Wheel-Housing.—The construction of rear wheel-housings shall be such that passengers cannot be injured as a result of tires bursting.

Fenders.—The construction of the fenders shall be such that no undue accumulation of dirt or foreign matter can be deposited on the body.

Exhaust.—The arrangement of the exhaust piping shall be such that the passengers will be adequately protected from the exhaust gases.

MOTORCOACH NOMENCLATURE

"Motorcoach" Considered Preferable to "Motorbus" as Standard Nomenclature

The Motorcoach Division of the Standards Committee has, in cooperation with the Equipment Committee of the American Electric Railway Association, agreed upon the following standard nomenclature for all types of motorcoaches, the term "motorcoach" being considered as preferable to the term "motorbus."

PROPOSED STANDARD NOMENCLATURE

City Type.—Single-Deck, having cross or longitudinal seats. Double-Deck, having cross or longitudinal seats.

Intercity Type.—Sedan, having multiple side-doors and full-width cross-seats. Parlor, having front and emergency doors and fixed or movable seats separated by an aisle.

Both the aisle and chair types of motorcoach have been classified as "parlor," as it is felt that recent development tends toward the same general type. The nomenclature proposed will be submitted at the Standards Committee Meeting for adoption as S.A.E. Recommended Practice.

COMPRESSION-TYPE FITTINGS EXTENDED

3/8, 7/16 and 1/2-In. Sizes, Rejected in January, To Be Resubmitted

At the January meeting of the Standards Committee the recommendation of the Parts and Fittings Division covering the compression-type of fuel and lubrication tube-fittings was accepted in part only, the ⅜, 7/16 and ½-in. sizes being referred back to the Division for further consideration, owing to criticism of the non-standard threads specified for the larger fittings.

At a special meeting held in Detroit on April 17 the Subdivision on Fuel and Lubrication Tube-Fittings reviewed the criticisms made at the Standards Committee Meeting. Those present were W. C. Keys, of the Gabriel Snubber Sales & Service Co., who acted as chairman; Arthur Boor, of the Willys-Overland Co.; C. J. Bopp, of the Packard Motor Car Co.; F. W. Borck, of the Commonwealth Brass Corporation; C. A. Hill, of the Mueller Brass Co.; W. H. Hollister, of the Imperial Brass Mfg. Co.; D. M. Pierson, of Dodge Bros.; and A. W. Reader, of the General Motors Corporation.

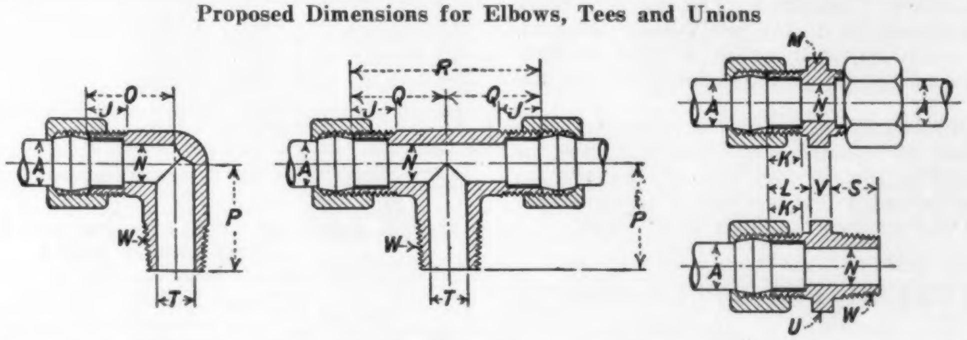
The present recommended practice, extended to include the ⅜, 7/16 and ½-in. sizes, revised as proposed by the Subdivision, is given herewith. The principal changes proposed by the Subdivision are:

For the ⅜-in. size, the thread *F* to be 15/32 in.-24 instead of 9/16 in.-24.

In the 7/16-in. size, the thread *F* to be 19/32 in.-24 instead of ⅝ in.-24 and Dimension *J* to be 11/32 instead of 13/32 in.

With reference to the thread for the ⅜-in. fitting, as

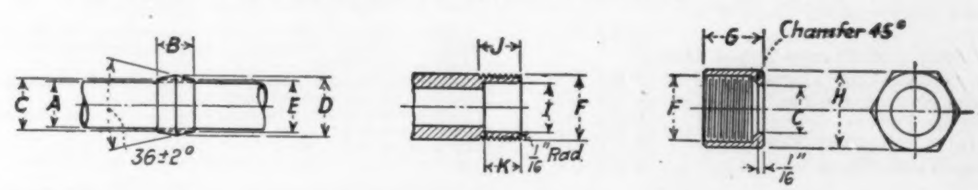
Proposed Dimensions for Elbows, Tees and Unions



Tubing Diameter *A*	*L*	Diameter of Hexagon *M*	*N*	*O*	*P*	*Q*	*R*	*S*	*T*	Diameter of Hexagon *U*	*V*	*W*[1]
⅛	¼	5/16	3/32	⅝	11/16	11/16	1⅜	⅜	3/16	7/16	5/32	⅛
3/16	9/32	⅜	⅛	⅝	11/16	11/16	1⅜	⅜	3/16	7/16	3/16	⅛
¼	5/16	7/16	3/16	⅝	¾	11/16	1⅜	⅜	3/16	7/16	3/16	⅛
5/16	11/32	½	¼	⅝	¾	11/16	1⅜	⅜	15/64	½	3/16	⅛
⅜	⅜	9/16	5/16	¾	⅞	13/16	1⅝	7/16	5/16	9/16	7/32	¼
7/16	13/32	⅝	11/32	27/32	1	29/32	1 13/16	7/16	5/16	⅝	7/32	¼
½	7/16	11/16	13/32	15/16	1⅛	1	2	½	13/32	11/16	7/32	⅜

All dimensions in inches.
[1] American Standard Pipe Thread.
Both ends of the unions shall be chamfered 45 deg. to the flats.

Proposed Dimensions for Sleeves, Nuts and Straight Threaded-Ends



Tubing Diameter *A* ±0.002	*B*	Sleeve Bore *C* ±0.002	Stock Diameter[1] *D*	Small Diameter of Taper *E*	*F*	Pitch Diameters[2] Max.	Pitch Diameters[2] Min.	*G*	*H*	*I* ±0.002	*J* Minimum	*K*[3]
⅛	3/16	0.130	3/16	0.140	5/16–24	0.2854	0.2821	⅜	⅜	0.136	¼	3/16
3/16	7/32	0.193	17/64	0.205	⅜–24	0.3479	0.3446	13/32	7/16	0.196	9/32	7/32
¼	¼	0.257	11/32	0.269	7/16–24	0.4104	0.4071	7/16	½	0.261	5/16	¼
5/16	¼	0.323	13/32	0.335	½–24	0.4729	0.4695	7/16	9/16	0.328	11/32	9/32
⅜	¼	0.386	15/32	0.398	9/16–24	0.5354	0.5318	15/32	⅝	0.391	⅜	5/16
7/16	5/16	0.444	17/32	0.455	⅝–24	0.5979	0.5941	½	11/16	0.449	13/32	11/32
½	⅜	0.515	⅝	0.527	11/16–20	0.6550	0.6509	⅝	13/16	0.531	7/16	⅜

All dimensions in inches.
[1] A short flat will appear on the sleeves for the ¼, 5/16 and ⅜-in. sizes as a result of the stock diameters selected.
[2] The pitch-diameters are based on the Class-D Tolerances for special diameters and pitches specified in the report of the National Screw Thread Commission.
[3] Also minimum usable length of threads on the double-end straight fitting.

present practice of the three largest manufacturers of fittings is divided between the standard 9/16 in.-24 thread and the non-standard 17/32 in.-24 thread, the standard thread is recommended.

As the thread pitch is the same throughout the range of sizes up to the ½-in. size, it is thought that the thread tolerances should increase in proportion to the diameter. Pitch-diameters based on the Class-D tolerances for special diameters and pitches, specified in the report of the National Screw Thread Commission, are therefore recommended. These tolerances have been reviewed by the Screw-Threads Division and found to be satisfactory.

The recommendation on compression-type tube-fittings was first considered by the Standards Committee in 1922, the first report of the Subdivision being published in June, 1923. As a result of differences of opinion, the report was referred back to the Subdivision several times by both the Division and the Standards Committee. The revisions made in the original recommendation during this period, taken individually, were of minor importance, but in their entirety represented a careful refinement and correlation of the different dimensions.

The adoption of this standard, revised as proposed, does not insure the users of constructions incorporating the standard against liability for infringement of any patents that exist and is not intended to constitute a recommendation of any patented applications that may be involved.

EXTRA-FINE THREAD FIT APPLICATIONS

Supplementary Report Completes Present Information on Screw-Thread Fits

In the report submitted at the last Annual Meeting of the Standards Committee, the Screw-Threads Division indicated the screw-thread fits that should be used for the different threads specified in the S.A.E. Standards and Recommended Practices. No tolerances were recommended for extra-fine threads because the report on screw-thread tolerances did not cover this series. In view of the report to be submitted at the Standards Committee Meeting, on Fits and Tolerances for the Extra-Fine Screw-Thread Series, the Screw-Threads Division recommends the following fit applications:

SCREW-THREAD FIT APPLICATIONS

Data Sheet	Class	Fit Classification
C13	Square Fittings	NEF-C
C15	Taper Fittings	NEF-C
C46	Fuel and Lubrication Tube-Fittings (Soldered and Flared-Types Only)	NEF-C
C57	Oil and Grease-Cup Threads	NEF-C
C58a	Tank and Radiator Caps	NEF-B
C75	Tachometer Drive	NEF-C
E6b	Three-Joint Propeller-Shafts	NEF-C
J4	Steering-Wheel Hubs	NEF-C

It will be found that in the case of certain of the above standards some non-standard threads that are not covered by the standard screw-thread tolerance tables are included. An exception to this is the No. 10-40 thread for the square and taper fittings which has been included in the Division recommendation for Screw-Thread Tolerances.

EXTRA-FINE THREAD FITS RECOMMENDED

Report by Earle Buckingham Completes Work on Tolerances for S.A.E. Thread Series

The Screw-Threads Division Report, submitted in February, 1924, covered the tolerances for the S.A.E. Coarse and Fine-Thread Series. The report was based largely on the report of the Sectional Committee on the Standardization and Unification of Screw-Threads, organized under the rules of procedure of the American Engineering Standards Committee by the American Society of Mechanical Engineers and the Society of Automotive Engineers, which was prepared in collaboration with the National Screw Thread Commission on which the American Society of Mechanical Engineers and the Society of Automotive Engineers are the two civilian participating organizations. In this report tolerances for the S.A.E. Extra-Fine Screw-Thread Series were not included, because this Series was not included in the report of the National Screw-Thread Commission.

As the Extra-Fine Thread Series is widely used in the automotive industry, Earle Buckingham, of the Niles-Bement-Pond Co., was appointed a subdivision of one to draft a report covering tolerances for this Series. His report, based on Section 4 of the National Screw Thread Commission, was submitted in May and was approved by the Screw-Threads Division by letter ballot. The report, which is given herewith, is a continuation of the screw-thread-tolerance tables printed on pp. C1 to C1m of the S.A.E. HANDBOOK.

TABLE 14—BASIC DIAMETERS AND THREAD DATA FOR THE EXTRA-FINE THREAD SERIES

Sizes	Threads Per Inch	Basic Major Diameter	Basic Pitch Diameter	Basic Minor Diameter	Pitch[1]	Basic Depth of Thread
10	40	0.1900	0.1738	0.1575	0.0250000	0.01624
¼	36	0.2500	0.2320	0.2139	0.0277778	0.01804
5/16	32	0.3125	0.2922	0.2719	0.0312500	0.02030
⅜	32	0.3750	0.3547	0.3344	0.0312500	0.02030
7/16	28	0.4375	0.4143	0.3911	0.0357143	0.02319
½	28	0.5000	0.4768	0.4536	0.0357143	0.02319
9/16	24	0.5625	0.5354	0.5084	0.0416667	0.02706
⅝	24	0.6250	0.5979	0.5709	0.0416667	0.02706
¾	20	0.7500	0.7175	0.6850	0.0500000	0.03248
⅞	20	0.8750	0.8425	0.8100	0.0500000	0.03248
1	20	1.0000	0.9675	0.9350	0.0500000	0.03248
1⅛	18	1.1250	1.0889	1.0528	0.0555556	0.03608
1¼	18	1.2500	1.2139	1.1778	0.0555556	0.03608
1½	18	1.5000	1.4639	1.4278	0.0555556	0.03608
1¾	16	1.7500	1.7094	1.6778	0.0625000	0.04060
2	16	2.0000	1.9594	1.9278	0.0625000	0.04060
2¼	16	2.2500	2.2094	2.1778	0.0625000	0.04060
2½	16	2.5000	2.4594	2.4278	0.0625000	0.04060
2¾	16	2.7500	2.7094	2.6778	0.0625000	0.04060
3	16	3.0000	2.9594	2.9278	0.0625000	0.04060
3½	16	3.5000	3.4594	3.4278	0.0625000	0.04060
4	16	4.0000	3.9594	3.9278	0.0625000	0.04060

[1] This column is given to seven decimal places for computation purposes only.

TABLE 15—LOOSE FIT (CLASS B) FOR SCREWS IN THE EXTRA-FINE THREAD SERIES[1]

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Maximum[4] Minor Diameter
		Maximum[2]	Tolerance	Minimum	Maximum[2]	Tolerance[3]	Minimum	
10	40	0.1900	0.0068	0.1832	0.1738	0.0043	0.1695	0.1593
¼	36	0.2500	0.0072	0.2428	0.2320	0.0046	0.2274	0.2159
5/16	32	0.3125	0.0076	0.3049	0.2922	0.0050	0.2872	0.2742
⅜	32	0.3750	0.0076	0.3674	0.3547	0.0051	0.3496	0.3367
7/16	28	0.4375	0.0086	0.4289	0.4143	0.0055	0.4088	0.3937
½	28	0.5000	0.0086	0.4914	0.4768	0.0056	0.4712	0.4562
9/16	24	0.5625	0.0092	0.5533	0.5354	0.0060	0.5294	0.5114
⅝	24	0.6250	0.0092	0.6158	0.5979	0.0061	0.5918	0.5739
¾	20	0.7500	0.0102	0.7398	0.7175	0.0067	0.7108	0.6887
⅞	20	0.8750	0.0102	0.8648	0.8425	0.0068	0.8357	0.8137
1	20	1.0000	0.0102	0.9898	0.9675	0.0070	0.9605	0.9387
1⅛	18	1.1250	0.0114	1.1136	1.0889	0.0074	1.0815	1.0568
1¼	18	1.2500	0.0114	1.2386	1.2139	0.0075	1.2064	1.1818
1½	18	1.5000	0.0114	1.4886	1.4639	0.0077	1.4562	1.4318
1¾	16	1.7500	0.0126	1.7374	1.7094	0.0083	1.7011	1.6733
2	16	2.0000	0.0126	1.9874	1.9594	0.0085	1.9509	1.9233
2¼	16	2.2500	0.0126	2.2374	2.2094	0.0086	2.2008	2.1733
2½	16	2.5000	0.0126	2.4874	2.4594	0.0088	2.4506	2.4233
2¾	16	2.7500	0.0126	2.7374	2.7094	0.0089	2.7005	2.6733
3	16	3.0000	0.0126	2.9874	2.9594	0.0091	2.9503	2.9233
3½	16	3.5000	0.0126	3.4874	3.4594	0.0094	3.4500	3.4233
4	16	4.0000	0.0126	3.9874	3.9594	0.0096	3.9498	3.9233

[1] Based on 1924 Report of the National Screw Thread Commission, using a standard length of engagement of five threads.
[2] Basic diameter.
[3] The tolerances specified for pitch diameter are cumulative and include errors of lead and angle.
[4] Dimensions given are figured to the intersection of the worn tool arc with a centerline through crest and root. Minimum flat at root equals ⅛ x *p*.

TABLE 16—LOOSE FIT (CLASS B) FOR NUTS IN THE EXTRA-FINE THREAD SERIES[1]

Size	Threads Per Inch	Minimum Major Diameter[2]	Pitch Diameter			Minor Diameter		
			Minimum[3]	Tolerance[4]	Maximum	Minimum	Tolerance	Maximum
10	40	0.1900	0.1738	0.0043	0.1781	0.1629	0.0027	0.1656
1/4	36	0.2500	0.2320	0.0046	0.2366	0.2199	0.0030	0.2229
5/16	32	0.3125	0.2922	0.0050	0.2972	0.2787	0.0034	0.2821
3/8	32	0.3750	0.3547	0.0051	0.3598	0.3412	0.0034	0.3446
7/16	28	0.4375	0.4143	0.0055	0.4198	0.3988	0.0039	0.4027
1/2	28	0.5000	0.4768	0.0056	0.4824	0.4613	0.0039	0.4652
9/16	24	0.5625	0.5354	0.0060	0.5414	0.5174	0.0045	0.5219
5/8	24	0.6250	0.5979	0.0061	0.6040	0.5799	0.0045	0.5844
3/4	20	0.7500	0.7175	0.0067	0.7242	0.6959	0.0054	0.7013
7/8	20	0.8750	0.8425	0.0068	0.8493	0.8209	0.0054	0.8263
1	20	1.0000	0.9675	0.0070	0.9745	0.9459	0.0054	0.9513
1 1/8	18	1.1250	1.0889	0.0074	1.0963	1.0649	0.0060	1.0709
1 1/4	18	1.2500	1.2139	0.0075	1.2214	1.1899	0.0060	1.1959
1 1/2	18	1.5000	1.4639	0.0077	1.4716	1.4399	0.0060	1.4459
1 3/4	16	1.7500	1.7094	0.0083	1.7177	1.6823	0.0068	1.6891
2	16	2.0000	1.9594	0.0085	1.9679	1.9323	0.0068	1.9391
2 1/4	16	2.2500	2.2094	0.0086	2.2180	2.1823	0.0068	2.1891
2 1/2	16	2.5000	2.4594	0.0088	2.4682	2.4323	0.0068	2.4391
2 3/4	16	2.7500	2.7094	0.0089	2.7183	2.6823	0.0068	2.6891
3	16	3.0000	2.9594	0.0091	2.9685	2.9323	0.0068	2.9391
3 1/2	16	3.5000	3.4594	0.0094	3.4688	3.4323	0.0068	3.4391
4	16	4.0000	3.9594	0.0096	3.9690	3.9323	0.0068	3.9391

[1] Based on 1924 Report of the National Screw Thread Commission using a standard length of engagement of five threads.
[2] Basic diameter. Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "Go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals 1/24 x *p*.
[3] Basic diameter.
[4] The tolerances specified for pitch diameter are cumulative and include errors of lead and angle.

TABLE 17—FREE FIT (CLASS C) FOR SCREWS IN THE EXTRA-FINE THREAD SERIES[1]

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Maximum Minor Diameter[4]
		Maximum[2]	Tolerance	Minimum	Maximum[2]	Tolerance[3]	Minimum	
10	40	0.1900	0.0048	0.1852	0.1738	0.0027	0.1711	0.1593
1/4	36	0.2500	0.0050	0.2450	0.2320	0.0030	0.2290	0.2159
5/16	32	0.3125	0.0054	0.3071	0.2922	0.0032	0.2890	0.2742
3/8	32	0.3750	0.0054	0.3696	0.3547	0.0033	0.3514	0.3367
7/16	28	0.4375	0.0062	0.4313	0.4143	0.0036	0.4107	0.3937
1/2	28	0.5000	0.0062	0.4938	0.4768	0.0037	0.4731	0.4562
9/16	24	0.5625	0.0066	0.5559	0.5354	0.0040	0.5314	0.5114
5/8	24	0.6250	0.0066	0.6184	0.5979	0.0041	0.5938	0.5739
3/4	20	0.7500	0.0072	0.7428	0.7175	0.0045	0.7130	0.6887
7/8	20	0.8750	0.0072	0.8678	0.8425	0.0046	0.8359	0.8137
1	20	1.0000	0.0072	0.9928	0.9675	0.0047	0.9628	0.9387
1 1/8	18	1.1250	0.0082	1.1168	1.0889	0.0050	1.0839	1.0568
1 1/4	18	1.2500	0.0082	1.2418	1.2139	0.0051	1.2088	1.1818
1 1/2	18	1.5000	0.0082	1.4918	1.4639	0.0054	1.4585	1.4318
1 3/4	16	1.7500	0.0090	1.7410	1.7094	0.0058	1.7036	1.6733
2	16	2.0000	0.0090	1.9910	1.9594	0.0060	1.9534	1.9233
2 1/4	16	2.2500	0.0090	2.2410	2.2094	0.0061	2.2033	2.1733
2 1/2	16	2.5000	0.0090	2.4910	2.4594	0.0063	2.4531	2.4233
2 3/4	16	2.7500	0.0090	2.7410	2.7094	0.0064	2.7030	2.6733
3	16	3.0000	0.0090	2.9910	2.9594	0.0066	2.9528	2.9233
3 1/2	16	3.5000	0.0090	3.4910	3.4594	0.0069	3.4525	3.4233
4	16	4.0000	0.0090	3.9910	3.9594	0.0071	3.9523	3.9233

[1] Based on 1924 Report of the National Screw Thread Commission, using a standard length of engagement of five threads.
[2] Basic diameter.
[3] The tolerances specified for pitch diameter are cumulative and include errors of lead and angle.
[4] Dimensions given are figured to the intersection of the worn tool arc with a centerline through crest and root. Minimum flat at root equals 1/8 x *p*.

TABLE 18—FREE FIT (CLASS C) FOR NUTS IN THE EXTRA-FINE THREAD SERIES[1]

Size	Threads Per Inch	Minimum Major Diameter[2]	Pitch Diameter			Minor Diameter		
			Minimum[3]	Tolerance[4]	Maximum	Minimum	Tolerance	Maximum
10	40	0.1900	0.1738	0.0027	0.1765	0.1629	0.0027	0.1656
1/4	36	0.2500	0.2320	0.0030	0.2350	0.2199	0.0030	0.2229
5/16	32	0.3125	0.2922	0.0032	0.2954	0.2787	0.0034	0.2821
3/8	32	0.3750	0.3547	0.0033	0.3580	0.3412	0.0034	0.3446
7/16	28	0.4375	0.4143	0.0036	0.4179	0.3988	0.0039	0.4027
1/2	28	0.5000	0.4768	0.0037	0.4805	0.4613	0.0039	0.4652
9/16	24	0.5625	0.5354	0.0040	0.5394	0.5174	0.0045	0.5219
5/8	24	0.6250	0.5979	0.0041	0.6020	0.5799	0.0045	0.5844
3/4	20	0.7500	0.7175	0.0045	0.7220	0.6959	0.0054	0.7013
7/8	20	0.8750	0.8425	0.0046	0.8471	0.8209	0.0054	0.8263
1	20	1.0000	0.9675	0.0047	0.9722	0,9459	0.0054	0.9513
1 1/8	18	1.1250	1.0889	0.0050	1.0939	1.0649	0.0060	1.0709
1 1/4	18	1.2500	1.2139	0.0051	1.2190	1.1899	0.0060	1.1959
1 1/2	18	1.5000	1.4639	0.0054	1.4693	1.4399	0.0060	1.4459
1 3/4	16	1.7500	1.7094	0.0058	1.7152	1.6823	0.0068	1.6891
2	16	2.0000	1.9594	0.0060	1.9654	1.9323	0.0068	1.9391
2 1/4	16	2.2500	2.2094	0.0061	2.2155	2.1823	0.0068	2.1891
2 1/2	16	2.5000	2.4594	0.0063	2.4657	2.4323	0.0068	2.4391
2 3/4	16	2.7500	2.7094	0.0064	2.7158	2.6823	0.0068	2.6891
3	16	3.0000	2.9594	0.0066	2.9660	2.9323	0.0068	2.9391
3 1/2	16	3.5000	3.4594	0.0069	3.4663	3.4323	0.0068	3.4391
4	16	4.0000	3.9594	0.0071	3.9665	3.9323	0.0068	3.9391

[1] Based on 1924 Report of the National Screw Thread Commission, using a standard length of engagement of five threads.
[2] Basic diameter. Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "Go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals 1/24 x *p*.
[3] Basic diameter.
[4] The tolerances specified for pitch diameter are cumulative and include errors of lead and angle.

TABLE 19—MEDIUM FIT (CLASS D) FOR SCREWS IN THE EXTRA-FINE THREAD SERIES[1]

Size	Threads Per Inch	Major Diameter			Pitch Diameter			Maximum Minor Diameter[4]
		Maximum[2]	Tolerance	Minimum	Maximum[3]	Tolerance[3]	Minimum	
10	40	0.1900	0.0048	0.1852	0.1738	0.0019	0.1719	0.1593
1/4	36	0.2500	0.0050	0.2450	0.2320	0.0021	0.2299	0.2159
5/16	32	0.3125	0.0054	0.3071	0.2922	0.0023	0.2899	0.2742
3/8	32	0.3750	0.0054	0.3696	0.3547	0.0024	0.3523	0.3367
7/16	28	0.4325	0.0062	0.4313	0.4143	0.0026	0.4117	0.3937
1/2	28	0.5000	0.0062	0.4938	0.4768	0.0027	0.4741	0.4562
9/16	24	0.5625	0.0066	0.5559	0.5354	0.0029	0.5325	0.5114
5/8	24	0.6250	0.0066	0.6184	0.5979	0.0030	0.5949	0.5739
3/4	20	0.7500	0.0072	0.7428	0.7175	0.0034	0.7141	0.6887
7/8	20	0.8750	0.0072	0.8678	0.8425	0.0035	0.8390	0.8137
1	20	1.0000	0.0072	0.9928	0.9675	0.0036	0.9639	0.9387
1 1/8	18	1.1250	0.0082	1.1168	1.0889	0.0039	1.0850	1.0568
1 1/4	18	1.2500	0.0082	1.2418	1.2139	0.0040	1.2099	1.1818
1 1/2	18	1.5000	0.0082	1.4918	1.4639	0.0042	1.4597	1.4318
1 3/4	16	1.7500	0.0090	1.7410	1.7094	0.0045	1.7049	1.6733
2	16	2.0000	0.0090	1.9910	1.9594	0.0047	1.9547	1.9233
2 1/4	16	2.2500	0.0090	2.2410	2.2094	0.0049	2.2045	2.1733
2 1/2	16	2.5000	0.0090	2.4910	2.4594	0.0050	2.4544	2.4233
2 3/4	16	2.7500	0.0090	2.7410	2.7094	0.0052	2.7042	2.6733
3	16	3.0000	0.0090	2.9910	2.9594	0.0053	2.9541	2.9233
3 1/2	16	3.5000	0.0090	3.4910	3.4594	0.0056	3.4538	3.4233
4	16	4.0000	0.0090	3.9910	3.9594	0.0059	3.9535	3.9233

[1] Based on 1924 Report of the National Screw Thread Commission, using a standard length of engagement of five threads.
[2] Basic diameter.
[3] The tolerances specified for pitch diameter are cumulative and include errors of lead and angle.
[4] Dimensions given are figured to the intersection of the worn tool arc with a centerline through crest and root. Minimum flat at root equals 1/8 x *p*.

TABLE 20—MEDIUM FIT (CLASS D) FOR NUTS IN THE EXTRA-FINE THREAD SERIES[1]

Size	Threads Per Inch	Minimum Major Diameter[2]	Pitch Diameter			Minor Diameter		
			Minimum[3]	Tolerance[4]	Maximum	Minimum	Tolerance	Maximum
10	40	0.1900	0.1738	0.0019	0.1757	0.1629	0.0027	0.1656
1/4	36	0.2500	0.2320	0.0021	0.2341	0.2199	0.0030	0.2229
5/16	32	0.3125	0.2922	0.0023	0.2945	0.2787	0.0034	0.2821
3/8	32	0.3750	0.3547	0.0024	0.3571	0.3412	0.0034	0.3446
7/16	28	0.4375	0.4143	0.0026	0.4169	0.3988	0.0039	0.4027
1/2	28	0.5000	0.4768	0.0027	0.4795	0.4613	0.0039	0.4652
9/16	24	0.5625	0.5354	0.0029	0.5383	0.5174	0.0045	0.5219
5/8	24	0.6250	0.5979	0.0030	0.6009	0.5799	0.0045	0.5844
3/4	20	0.7500	0.7175	0.0034	0.7209	0.6959	0.0054	0.7013
7/8	20	0.8750	0.8425	0.0035	0.8460	0.8209	0.0054	0.8263
1	20	1.0000	0.9675	0.0036	0.9711	0.9459	0.0054	0.9513
1 1/8	18	1.1250	1.0889	0.0039	1.0928	1.0649	0.0060	1.0709
1 1/4	18	1.2500	1.2139	0.0040	1.2179	1.1899	0.0060	1.1959
1 1/2	18	1.5000	1.4639	0.0042	1.4681	1.4399	0.0060	1.4459
1 3/4	16	1.7500	1.7094	0.0045	1.7139	1.6823	0.0068	1.6891
2	16	2.0000	1.9594	0.0047	1.9641	1.9323	0.0068	1.9391
2 1/4	16	2.2500	2.2094	0.0049	2.2143	2.1823	0.0068	1.1891
2 1/2	16	2.5000	2.4594	0.0050	2.4644	2.4323	0.0068	2.4391
2 3/4	16	2.7500	2.7094	0.0052	2.7146	2.6823	0.0068	2.6891
3	16	3.0000	2.9594	0.0053	2.9647	2.9323	0.0068	2.9391
3 1/2	16	3.5000	3.4594	0.0056	3.4650	3.4323	0.0068	3.4391
4	16	4.0000	3.9594	0.0059	3.9653	3.9323	0.0068	3.9391

[1] Based on 1924 Report of the National Screw Thread Commission, using a standard length of engagement of five threads.

[2] Basic diameter. Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "Go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals 1/24 x *p*.

[3] Basic diameter.

[4] The tolerances specified for pitch diameter are cumulative and include errors of lead and angle.

BATTERY RATINGS AND CAPACITIES

Twenty-Hour Rating Considered Preferable to 5-Hr. or 5-Amp. Ratings

Since the action taken in January covering five sizes of motor-truck battery in the present S.A.E. Standard for Storage-Batteries, the Division has made a careful analysis of present practice of rating storage-batteries and the advantages and disadvantages of the different methods. As a result of this study, the Division definitely recommends that the present standard be revised to specify a 20-hr. instead of a 5-hr. time-rating.

Before making this recommendation, a comprehensive statement setting forth the reasons for and against the various ratings was submitted to the passenger-car and motor-truck engineers, and printed in the February issue of THE JOURNAL, p. 149, to determine the consensus of opinion of the industry. It was found that the industry as a whole preferred the time rating in place of the 5-amp. rating and that the capacities based on a 20-hr. rating would be more acceptable to the industry as they closely approximate the capacities based on the 5-amp. rating.

The Division also recommends that the present ampere-hour capacities be increased as, owing to the improvement in the art since the original standard was adopted, the present battery capacities have become exceedingly conservative. The revisions proposed in the present S.A.E. Standard are given hereinafter.

REVISED STORAGE-BATTERY RATINGS PROPOSED

Batteries for combined starting and lighting service shall have two ratings. The first rating shall indicate the lighting ability and shall be the capacity in ampere-hours of the battery when it is discharged continuously at the 20-hr. rate to a final voltage of not less than 1.75 per cell, the temperature of the battery at the beginning of such discharge being 80 deg. fahr. The second rating shall indicate the starting ability and shall be the minimum amperes when the battery is discharged continuously at the 20-min. rate to a final voltage of not less than 1.5 per cell, the temperature of the battery at the beginning of such discharge being 80 deg. fahr.

REVISED CAPACITIES FOR S.A.E. STANDARD BATTERIES

Battery No.	Minimum Amp-Hr., 20-Hr. Rate	Minimum Amp. for 20 Min.
1	80	95
2	95	111
3	110	127
4	125	143
5	125	137
6	50	57
7	80	95
11	56	...
12	74	...
13	92	112
14	110	134
15	128	156

RECOMMENDED PRACTICES CANCELLED

The Aeronautic Division has recommended that the present S.A.E. Recommended Practices for Marking of Pipe-Lines, Systems of Measurements, and Gaging of Sheet Metal, Rods, Tubes, Wires and Cables as published on p. K43 of the S.A.E. HANDBOOK be cancelled in view of the fact that the marking of pipe-lines is covered in the proposed Aeronautical Safety Code and the measurement and gaging of aircraft parts and materials is a matter of practice that need not be necessarily in printed form.

RADIAL ENGINES

CERTAIN difficulties experienced with the rotary engine disappear with the static radial type, and it is possible to build this in considerably higher powers. Engines of 400 b. hp. are in regular production, and serious proposals have been made for units of twice that power, in the design and the construction of which no insuperable difficulty should be encountered. Static air-cooled radial engines may be run continuously at piston speeds exceeding 2000 ft. per min. and at brake mean effective pressures of more than 120 lb. per sq. in. at normal speed, the weight per brake horsepower being considerably less than 2 lb. In this class of engine the practical limit in size and speed is set by the loading and the rubbing speed of the big-end bearing. Attempts to use ball or roller bearings on the crankpins of large radial engines have been attended by great difficulties and many failures, owing to the destruction of the bearings by the high combined centrifugal and shock loadings. Plain big-end bearings enable the dimensions and the weight of the master connecting-rod to be kept within reasonable limits, and therefore the number of revolutions to be increased, but the design of a split big-end to take a number of articulated rods is by no means a simple matter.

Unlike the rotary engine, which is carried by its crankshaft through the medium of the ball or roller bearings, the static radial engine may be mounted by its crankcase directly upon the end of the fuselage or upon a special fixed or hinged mounting plate. This makes a much simpler mounting than the line or V engine, and facilitates the removal and replacement of the engine in the machine. The single-throw crankshaft, and in less measure the double-throw crankshaft of twin-row radial engines, is short and stiff, and torsional vibrations are not troublesome, while it is possible to effect very good balance by simple weights on the crank webs.—*Automobile Engineer.*

Automobile-Supercharger Development during 1924

By David Gregg [1]

A LARGE increase in the use of superchargers on racing cars has occurred during the last year, and many important events in the United States and in foreign countries have been won by them. The development of the supercharger in the automotive field has been a direct result of the demand for greater power per unit of engine displacement. The first step in this direction was the introduction of the straight-line-eight engine. Dividing the limited piston-displacement among eight cylinders instead of four or six reduced the size and the weight of the reciprocating parts, thus allowing higher engine-speeds. At the same time, the smaller cylinders carried higher compressions without detonation.

While higher speeds and compression-ratios increased the power output, it became more difficult to fill the cylinders full of fresh charge at each induction stroke, due to the short time the intake-valves were open and to the high gas-velocities necessary to fill the cylinders in so short a time. As a result, volumetric efficiency was poor, and supercharging was resorted to in an effort to increase the power output. During the last year, three types of supercharger have been used on racing cars. First, the blower pumping air to the carbureters, as on the Mercedes; then the supercharged induction-system, as on the Duesenberg; and later a somewhat similar type on the Sunbeam cars.

The first use of the automobile supercharger was to increase the volumetric efficiency at high engine-speeds. This was accomplished by pumping air under pressure to the carbureters, increasing the density of the intake charge. No attempt was made to increase the maximum mean-effective-pressure, but merely to maintain this pressure at higher speeds. In the supercharged induction-system on the Duesenberg car three distinct steps were taken. First, doped fuel was used to permit higher compression-ratios without detonation. Then the combustion space was enlarged, lowering the compression-ratio, and a supercharger was used that would force the mixture into this space at a pressure greater than atmospheric, so that both the final pressure and volume were greater than in the unsupercharged engine. The third step was in placing the carbureter at the supercharger intake, making the supercharger act as a mechanical fuel-mixer. The higher final pressure, greater weight of charge and better vaporization, increased the power output some 40 per cent.

The blower-type supercharger supplying air under pressure to the carbureters has been in use for some time. It increases the volumetric efficiency of the engine and higher speeds can be obtained without peaking. As the pressure in the carbureter is above atmospheric, fuel is usually supplied by a pump, with a relief-valve to regulate the pressure. Where gravity head is used, a line is run from the supercharger to the top of the fuel-tank to balance the carbureter pressure. When the Root blower is used, some means must be employed to damp-out the pulsations for, if they coincide with the intake strokes, carburetion may be disturbed and some cylinders receive more charge than others. The blower-type supercharger is usually controlled by a clutch and a three-way valve. When starting up and at low power-output the engine is not supercharged. When full-throttle operation is reached the supercharger is placed in operation by means of the clutch, and compressed air is delivered to the carbureter, increasing the intake-pressure and the density of the charge.

On the Sunbeam cars, a Root blower is used with the carbureter on the intake side. To avoid excessive pressures, a spring-loaded valve allows part of the charge to re-circulate around the blower. In addition, a safety-valve is used to prevent damage by backfire. As this type of supercharger operates at relatively low speeds, there is little mixing of the fuel and air after the charge leaves the carbureter. The air-cooler used on the Sunbeam car between the supercharger and the intake-ports undoubtedly acts as a damper to smooth-out the blower pulsations, as well as to cool the charge. Tests on the Brooklands track have shown that a supercharger of this type gives excellent acceleration and power at low car-speeds, an important advantage for passenger cars. However, its mechanical complications may limit its use on racing cars, in the case of which acceleration and performance at speeds lower than 60 m.p.h. is of little importance.

The supercharged induction-system using a centrifugal compressor is simple and its characteristics are ideal for racing. The impeller, rotating in the compressor casing with several thousandths of an inch clearance on either side, is the only moving part. The compression-ratio depends on the tip speed of the impeller; hence, the mixture density increases with the engine speed, and the maximum pressure is delivered at high speed when it is most needed. Due to the very high rotational speeds of the impeller, the air and the fuel are mixed into a dry vapor that is easily distributed, giving perfect combustion and smooth running. A throttle placed between the carbureter and the supercharger gives complete control at all speeds from idling to wide-open. Freedom from pulsations, increase of pressure with speed, mechanical mixing of the intake charge, and simplicity make this system particularly well adapted to racing cars, as well as to passenger-car service.

The results of this year's automobile racing has amply justified the use of the supercharger, and has given a good comparison of the performance of the different types. It has passed the laboratory stage, and is ready for useful and economic application to passenger cars and trucks.

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BASIC INVENTIONS TO COME

EVERY scientific discovery creates new opportunities for basic inventions. The discovery of radio-activity implies basic invention of a character unprecedented in the history of science and engineering. The discovery of a method of making fused quartz cheaply has made it possible to invent what will be regarded as startling methods for utilizing ultra-violet radiation in industry. Biologists, like Haldane, even think that with the aid of ultra-violet rays and ferments we may do away with the farm and produce all the food we need in factories.—Waldemar Kaempfert.

The Automotive Airbrake —Why and How

By H. D. HUKILL[1]

DETROIT AND BUFFALO SECTIONS PAPER

STENOGRAPHIC reports of the discussions following the presentation of this paper at the meetings of the Detroit and Buffalo Sections on March 5 and 17 were submitted, after being edited for publication, to the author and the several speakers for correction before printing. The discussion is prefaced by a reprint of the abstract of the paper for the information of members who were not in attendance at either meeting and who may not have read the paper as published in THE JOURNAL for March, 1925.

ABSTRACT

IN an endeavor to find an engineering justification for the use of the airbrake on automotive vehicles, an investigation was first made as to what actually causes a car to stop when the brakes are applied; and it was ascertained that nothing that can take place within the car itself can directly influence the motion of the automobile as a unit, that its motion can be changed only by some force external to the car itself.

Four such forces are normally present, namely, wind resistance, road resistance, gravity, and the adhesion of the road to the wheels. The first two are negligible. Grades have a measurable effect on the stopping distance, but the force that actually stops the car is the last named: the force that is applied from a point external to and in a direction opposite to that of the motion of the automobile. This frictional force is called into existence by the resistance that the brake-bands offer to the continued rotation of the wheels, the maximum possible road adhesion occurring when it is equal to the coefficient of adhesion multiplied by the weight carried by the wheels. If the brake-band pressure is greater than the maximum possible adhesion, the wheels will lock and a transfer of energy will take place between the sliding tires and the surface of the road. The shortest possible stopping distance is obtained when all braked wheels are held just short of the point of locking throughout the duration of the stop.

Friction is defined as the resistance of two bodies in contact that opposes a change in their relative positions. When the friction is greater than a force that tends to produce motion, the friction is termed "static" friction, or friction of rest; when the impelling force is greater than the resistance of friction and one body slides over the other, the friction is termed "kinetic" friction, or friction of motion. Rolling friction between a rolling wheel and the road is static friction, for the point of contact does not move. For the sake of simplicity, this is termed "adhesion," to distinguish it from the kinetic friction that exists between the brake-band and the brake-drum mounted on the wheel.

Every surface, no matter how highly polished it may be, contains humps and depressions that tend to interlock or mesh with those of other surfaces, like the teeth of two gears. Static friction is always greater than kinetic friction because these humps and depressions have a greater opportunity of becoming interlocked. When in relative motion, two surfaces have not time in which to become interlocked, and each surface hits only the high spots of the other. Consequently, the friction becomes less as the velocity increases.

After these preliminary observations, the author discusses the variations of the coefficient of friction of different kinds of brake-lining under varying conditions, develops formulas to show the forces necessary to lock the wheels of a car under given conditions, and determines the amount of push of the pedal or pull of the lever that would be necessary to produce this effect with various arcs of contact between the brake-shoe and the drum.

With consideration for operating and maintenance requirements, the best practice in heavy-vehicle design is said to have determined that the maximum total multiplication between the pedal input and the cam output is about 36, and between the hand-lever and the cam, about 50. Inasmuch as an average man can exert a push of approximately 200 lb. on the pedal and a pull of 150 lb. on the hand-lever, the statement is made that, under the best possible operating conditions, either hand or foot-actuated rear-wheel brakes are inadequate to produce the shortest possible stop in any vehicle having a gross weight of more than 7500 lb. Under the worst combination of operating conditions, it is probable that the weight that could be so controlled would not exceed 3500 lb. If a braking pressure sufficient to lock the rear wheels is not available, the addition of front-wheel brakes operated from the same actuating source will not reduce the stopping distance, but, in fact, will increase it.

The limitations of propeller-shaft service or foot-brakes, or internal and external-band brakes, and of mechanically actuated and self-energizing servo-brakes are outlined, and the conclusion is reached that, in order adequately to brake vehicles weighing more than 5000 lb., a power brake is essential.

With the object of applying more force with greater flexibility to existing brake-riggings, the Westinghouse automotive airbrake has been developed, the details of which are described with copious illustrations.

THE DISCUSSION AT DETROIT

QUESTION:—What would be the weight of the airbrake mechanism for a four-wheel-brake car weighing 2500 lb.?

MR. HUKILL:—The total weight of airbrake equipment, with accumulator, would be between 50 and 60 lb., depending somewhat on the special levers and brackets required to connect into the brake linkage on the car. If the 3-cu. ft. air-compressor were included, the total weight would be increased about 25 lb.

QUESTION:—What has been the actual experience in connection with moisture in the valve mechanism and with freezing?

MR. HUKILL:—Some freezing was encountered with early equipments using the accumulator as a source of air supply because one of the products of combustion in the engine cylinder is water. Another product is an oily sludge that had a tendency to collect in the line between the accumulator and the reservoir. Freezing did not occur at the brake valve, as the condensate was trapped in the reservoir, and not in the air lines between the

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accumulator and the reservoir. With the compressor, no trouble results from freezing, because the relatively small volume of air required shows so little condensation of water that it is of no consequence. In some cases, two reservoirs are used in series to give double expansion, to insure that the air in the second reservoir is cooled down to atmospheric temperature before it passes through the lines to the brake chambers, which prevents the condensation of moisture in these lines.

QUESTION:—When do you recommend the use of the accumulator and when the use of the compressor?

MR. HUKILL:—The accumulator is recommended only for passenger cars and only when the system is installed after the car has been in service. If the airbrake equipment is installed as standard factory equipment the compressor would be recommended.

THE DISCUSSION AT BUFFALO

A MEMBER:—Mr. Hukill stated that the maximum retardation effort occurs just before the wheels lock. To my mind, you would get the greatest retardation when the slippage of the wheels is approximately 50 per cent.

MR. HUKILL:—Assuming that the brakes are equalized, there can be no point of 50-per cent wheel slippage. Suppose that at the instant of brake application the car has kinetic energy represented by KE. Then the actual stopping-distance $S = KE/F$, where F is the force imparted to the wheels to keep them rolling and is measured by the frictional force developed at the brake bands. The maximum value of $F = AW$, where A is the coefficient of wheel and road adhesion or, friction and W is the weight carried by the braked wheel. The static coefficient A of a rolling rubber-tired wheel on a hard dry road is ordinarily accepted as 0.6, although under certain conditions it may be considerably higher. The instant the wheel is locked and slides on the road, A becomes a coefficient of kinetic friction with a correspondingly lower value.

Since the shortest possible stopping-distance is $S = KE/AW$, the minimum value will be obtained when A is at a maximum value throughout the stop. This condition exists when the force applied to the brake bands is so regulated that the wheels are held just short of the point of locking. Should the wheels lock during the stoppage, the brakes should be released sufficiently to permit the wheels to rotate again if the minimum stopping-distance is desired. In actual practice and speaking of rear wheels only, the clutch should remain engaged until the car speed has been reduced to the idling-engine speed. For the reasons given, a car with unequalized brakes that allow one wheel to slide during a stop, cannot be stopped as quickly as the car with perfectly equalized brakes.

Regarding the apparent flexibility and smoothness of stopping with the airbrakes as compared with hydraulic and mechanical-linkage brakes, suppose a car to be on such a rough road that the rear wheels bounce clear off the surface. If the brakes are applied, the instant the wheel rises from the ground it is locked by the brake-band friction, but when it returns the road adhesion will again cause it to rotate against the action of the brake-band friction. With a solid-linkage connection or a column of incompressible liquid between the brakes and the pedal, however, this reaction is transmitted directly to the foot of the driver, whereas, with the airbrake the elastic volume of air in the brake chambers has a cushioning effect that reduces the seizing of the tires on the road and produces a smoother and shorter stop. This applies also to brake action under spring deflection on Hotchkiss drives with imperfect linkage layouts.

A MEMBER:—You mentioned the brake coefficient between the tire and ground as 0.6. Have you made coefficient tests with balloon tires and, if so, what was the coefficient?

MR. HUKILL:—We have not, but some of the tests made with high-pressure tires indicated, in some few instances, a coefficient of road adhesion as high as 0.80 or 0.85. This factor depends, of course, upon the type and characteristics of the tire as well as upon the kind and condition of road surface.

W. R. GORDON[2]:—How do oil and water on a steel shoe affect the coefficient of friction? Would the oil burn off, or would the brake become inoperative? Also, what pressure per square inch do you use on these shoes?

In making tests with airbrakes during the last 18 months, I have noticed that, while the airbrake is certainly a convenience for the driver, a perceptible interval of time seemed to elapse between applying the air and the taking-hold of the brake.

In the four-wheel-brake application that was shown on the screen, what would happen if there was a leaky hose; would the brake become inoperative or would it operate suddenly?

With the air compressor, have you had any trouble from the engine-oil gumming up?

MR. HUKILL:—Under ordinary service conditions, small quantities of oil or water have no noticeable effect. They are on the surface of the shoe only and are burned off quickly by the heat evolved during the application of the brake. The brakes are 100 per cent efficient in winter operation through snow and slush. With a continuous flow of grease the conditions are somewhat different. Last year we drove a Fageol double-deck bus, having a gross weight of about 18,000 lb., over the Lincoln Highway across the Allegheny Mountains in Pennsylvania. The car was operated for practically a continuous 24-hr. run and was kept in high gear on all of the down grades, which was a most severe brake-test. With the one-piece brake-drum and hub construction used, the heating was sufficient to melt the grease in the hubs and produce an almost continuous flow of semi-fluid grease to the brake-drum. A brake pressure higher than normal was required to make the brakeshoes take hold through the grease, and for this reason the service stops were somewhat rougher than usual but the brake did not lose its effectiveness. The likelihood of a recurrence of similar conditions was overcome later by ventilating the brake-drums and providing an adequate grease seal in the hubs.

The pressure on the brakeshoes, under maximum brake applications, is from 150 to 200 lb. per sq. in.

Mr. Gordon mentioned the time interval between applying the air and the brake taking hold. With the original equipment an appreciable lag occurred; this was reduced greatly, however, by the addition of an application-release valve, or relay valve. Recently we have also designed a brake valve of considerably greater capacity which has rendered the time interval imperceptible.

In case of a leaking connection or hose, the brake valve will maintain the line pressure against such leaks up to the capacity of the valve. It is possible to install double check-valves in the brake lines in such a way that complete rupturing of a line will seal that line, leaving all other brake lines fully effective, without leakage. Such a device is rather sensitive and often unreliable, so it is not recommended for general use. It is consid-

[2] M.S.A.E.—Transportation engineer, Pierce-Arrow Motor Car Co., Buffalo.

ered good practice to keep brake-application lines free from all restrictions where sludge and dirt may collect and clog or freeze. Tubing breakage or brake-chamber failure is practically unknown.

Oil gumming in a compressor is caused by carbonization of the oil at high temperature. The type B compressor is so designed that it may be operated continuously at its rated speed and pressure in a room with a temperature of 80 deg. fahr. and without any artificial cooling draft. Under these conditions the heating will not be sufficient to cause oil carbonization. In service installations, the compressor never is operated continuously at its maximum speed, and it usually is mounted so as to receive a cooling draft from the fan, so an ample margin of safety against overheating is provided.

A MEMBER:—Some German trucks that I had to do with after the war were equipped with metal brake-liners. They were of cast iron for a distance of about 3 in. and brass was used for a length of about 1 in. To determine why this construction was used, we removed the brass, and then we had trouble. It seemed that, with the combination of metals, the brakes operated satisfactorily because, as the cast iron wore excessively, it would score the drum but the brass provided a lubricant and, as the two metals wore alternately, no scoring occurred. I would like to know what Mr. Hukill uses for his brake metal.

MR. HUKILL:—When the metal brake was first developed, both the brakeshoes and the brake-drum were made from a supposedly mild steel. Excellent service results were obtained for some time but, after changing the source of steel supply, the life of the brakeshoes was considerably shorter. Investigation showed that the original steel supply had been rolled from scrap battleship armor plate. We are now using a 90-point carbon-steel shoe or a special 70-point carbon-steel with a small percentage of nickel and chromium. Drum liners are made from a 10 to 20-point carbon mild-steel. The brakeshoes and the liners take a polish, without scoring, and are noiseless in service because of the low unit pressures and very rigid construction. I think, you will find that many of the European passenger cars have metal-to-metal brakes.

L. H. POMEROY[3]:—As Mr. Hukill states, the prime function of the airbrake is to eliminate manual operation. While he has made his case very clear in regard to heavy vehicles, the value he has assumed of between 36 and 50 lb. as a leverage augment seems rather low, as, within my own experience, I have found most troubles arising when the leverage augment was from 120 to 150.

In regard to the mathematical derivation of the stopping force obtained from an internal brake, this force depends not only on the angle embraced on the brake-lining but also on the relation of the brake-lining to the fulcrum pin of the brakeshoe. Should the end of the brake-lining be so disposed with regard to the fulcrum that the tangent of the angle formed by the two lines, one from the end of the brake-lining to the fulcrum and one from the end of the brake-lining to the center of the wheel, is less than the coefficient of friction, the brakeshoe will positively lock.

I am pleased to note Mr. Hukill's advocacy of the internal-shoe type of brake. European experience with this type, which is far more extensive than American experience, has shown conclusively that two conditions must be fulfilled in successful expanding-shoe brakes; one is accurate workmanship and the other is extreme rigidity of the brake-drum, the brakeshoes and the operating mechanism. Given this rigidity, chattering and squeaking vanish. The serious objection to the wrapping type of brake, of either the internal or external form, is that a variation in the coefficient of friction appears as an index in the equation relating to brake tension and hence stopping power, so that a variation of from 0.35 to 0.25 in the coefficient of friction means a variation of 54 per cent in stopping force. This being the case, the futility of the average compensating mechanism is apparent.

It is necessary to do everything that is possible to increase the mechanical efficiency of the brake-operating mechanism, even to reducing the friction between the cam and the shoe. This is being done in Europe to the extent of using a ball-bearing thrust behind the face against which the cam operates, and when one considers the conditions when maximum pressure is applied between a dry cam and a dry shoe, it is obvious that the mechanical efficiency must be extremely low. It would seem, therefore, that while Mr. Hukill has put up a most excellent case for the advantages of airbrakes on heavy vehicles, considerable work still remains to be done on the detail improvement of brakes, which does not by any means diminish the advantages given by airbrakes but would make the application simpler than it is now.

MR. HUKILL:—The condition of brake locking described by Mr. Pomeroy is actually encountered in service. I know of such an occurrence with ordinary mechanical fabric-lined brakes, when a 21-in. brakeshoe was mounted on a brake spider originally intended for an 18-in. shoe. The geometry was such that, with a brake-lining friction coefficient of 0.5 or more, the brake was self-locking. The friction did occasionally reach this value and the slightest pedal operation would lock the system so that it was necessary to engage the reverse gear to release the brakes.

A MEMBER:—I am much interested in this subject from the standpoint of the axle manufacturer. We know that the ordinary liner is not what it should be. We have followed the practice of using soft material for the liner. In Mr. Hukill's tests, has he noticed any tendency for the liners to heat and has he had any trouble with dirt when the liners were opened?

MR. HUKILL:—The ventilated drum is just coming into use. No trouble whatever has been encountered with sand or dirt in this brake construction and we do not anticipate any. The ventilation ducts are merely to assist in cooling, although without them the heat radiation and the cooling of the metal brake is much quicker than with the fabric-lined brake, because fabric lining acts as an effective heat insulator.

MR. POMEROY:—Have you had any trouble with the rivets shearing off in the drum liner because of the difference in expansion through heating?

MR. HUKILL:—We have had no trouble with shearing of drum-liner rivets. Brakeshoes attached with $\frac{3}{8}$-in. bolts would shear the bolts, but no shearing of the $\frac{5}{8}$-in. bolts, that are used in general service, has occurred.

[3] M.S.A.E.—American Body Co., Buffalo.

The Flettner Rotor-Ship[1]

MAGNUS established by his experiments that a rotating cylindrical body blown upon at right angles to its axis by a wind, not only offers the usual resistance, but also receives a force directed toward that side of it on which the relative wind speed and peripheral speed are most nearly equal. Lord Rayleigh has dealt with similar phenomena in tennis balls, in a short essay on The Irregular Flight of a Tennis Ball. He mentions that a current must circulate around the ball, without going deeper into the question of this current. Lafay had already made similar measurements over 10 years before in Paris. The Gottingen laboratory repeated Lafay's experiments for purely theoretical reasons. I made the first experiments on water, on the Wannsee near Berlin, with a little model ship which carried a paper cylinder, driven by clockwork, and 15 cm. (5.91 in.) in diameter by 40 cm. (15.75 in.) high. As I heard later from Gottingen, the principle had already been proved to give much higher values than had been found by Lafay, even before we started the experiments from a practical point of view. So far, no even approximate estimate was possible of the force required to rotate the towers, of the weight of the high towers themselves, of the vibrations induced by the rotation of these great bodies, and the effect that this would have on the ship, of the behavior of the towers when not turning in gales, and so forth. The proposed large metal cylinders, which are arranged on the ship to turn freely, constituted indeed the most difficult scheme of the type attempted.

Effect of Wind Velocity on Rotating Cylinder

The effect on the rotating cylinder ceases to increase beyond a wind speed of about 12 m. (39.37 ft.) per sec. This

[1] From an abstract of a paper read before a meeting of the Schiffbautechischen Gesellschaft by Von Auton Flettner.

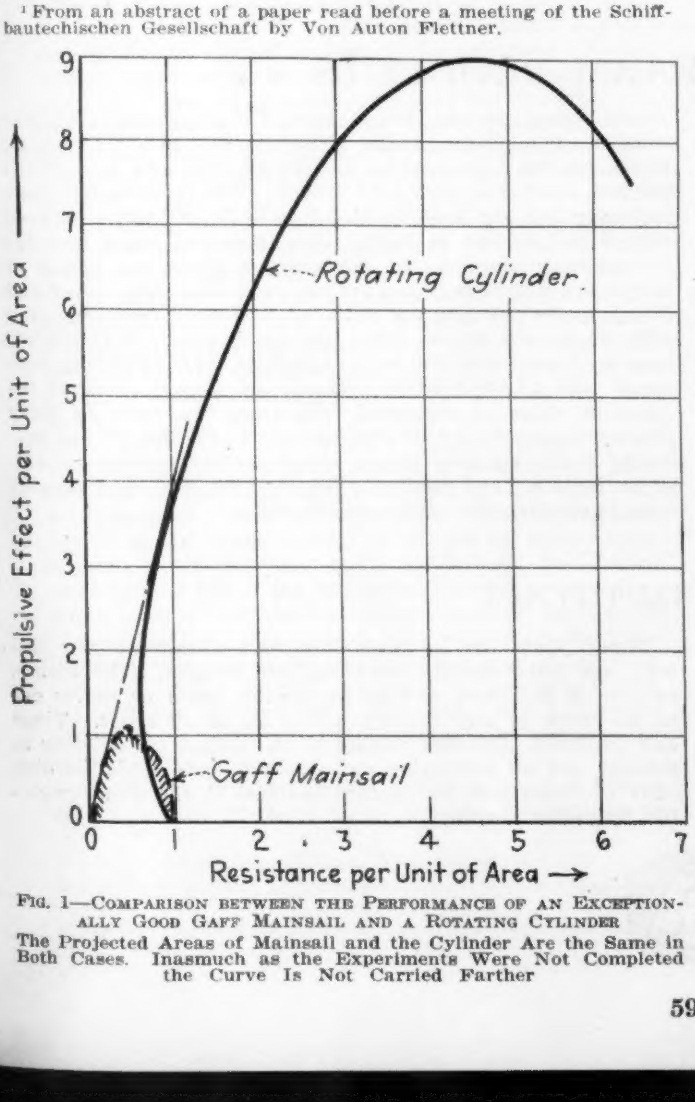

FIG. 1—COMPARISON BETWEEN THE PERFORMANCE OF AN EXCEPTIONALLY GOOD GAFF MAINSAIL AND A ROTATING CYLINDER
The Projected Areas of Mainsail and the Cylinder Are the Same in Both Cases. Inasmuch as the Experiments Were Not Completed the Curve Is Not Carried Farther

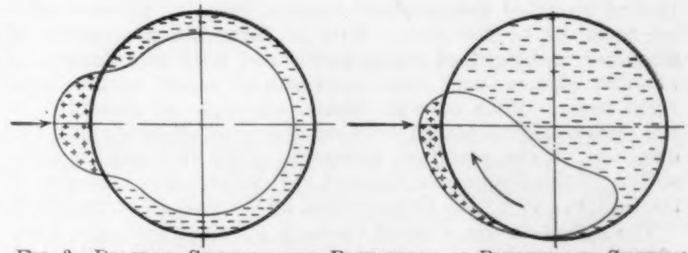

FIG. 2—DIAGRAM SHOWING THE PROPORTION OF PRESSURE TO SUCTION ON A NON-ROTATING CYLINDER (AT THE LEFT) AND (AT THE RIGHT) WHEN THE CYLINDER ROTATES
In Both Instances the Area Denoting Pressure Is Marked with Plus Signs and That of Suction with Minus Signs. The Arrow at the Left of Both Drawings Indicates the Direction of the Wind

is a matter of the greatest practical importance. No more force is taken from the highest winds than is appropriate to the peripheral speed. This advantage cannot be too strongly emphasized from the point of view of sailing. The mariner will always be able to derive propulsive power from the strongest gales, provided, of course, that he is not prevented by nautical reasons, such as too high a sea. Should the rotor for any reason stop rotating, the resistance of the cylinder is very much less than that of the bare rigging.

The advantage of the rotating cylinders, compared with sails is enormous. More than 10 times the power derived from sails is given by the rotating cylinder. Fig. 1 shows the comparison between the performance of an exceptionally good gaff mainsail and a rotating cylinder of the same projected area. The curve was not carried farther since the experiments were not completed.

With regard to the theory of the Magnus effect, it is not yet possible to describe exactly the action of the wind currents. Professor Prandtl's "boundary-layer" theory, however, provides a plausible explanation of the phenomenon. He asserted 20 years ago that the frictional effect of a fluid is restricted mainly to a proportionately thin layer near the body, that is, to the so-called "boundary layer" which in most cases prevents the formation of ideal stream-lines according to the "potential" theory. When a true potential current meets a rotary current of very great velocity, the astonishing effect of this condition of current round a rotating cylinder is the sudden increase of pressure. Under the full influence of the "boundary layer", such a rise in pressure would not be possible. The rise in pressure would have to result much more gradually. With the cylinder motionless, the "boundary layer" breaks away more or less symmetrically to the direction of the current, shortly after crossing the zone of lowest pressure. With rotation, this breaking away is markedly unsymmetrical, resulting in asymmetry of the stream, and hence in a propulsive force. The higher the speed of rotation, the more the point of the break away is shifted. After close study of the phenomena, the view is suggested that the air becomes diverted into a rotary current in a wide area around the cylinder.

Direction of Resultant Force and Wind

The drawing at the left of Fig. 2 shows the proportion of pressure to suction on a non-rotating cylinder as has already been described by Lafay and others. The area denoting pressure is marked with plus signs, and that of suction with minus signs. The drawing at the right indicates the distribution of pressure when the cylinder rotates at a peripheral speed which is three or four times that of the wind.

I have always laid emphasis on the fact that in all applications of the laws concerning currents, the low-pressure side is the most important and that when it is desired to utilize to the fullest extent the forces latent in currents, the side of low pressure must be considered first and care taken to make use of the possibility to induce a high degree of suction. In aircraft design, this point has been made the most of by

practically every designer. Our problem was to construct a rotating cylinder in such a way that the resultant force would act as nearly as possible at right angles to the direction of the wind. It may be taken for granted that, with a very high proportion of the surface speed of the tower to that of the wind, the resultant departs from the perpendicular by from 90 to 130 deg. With a favorable proportion of diameter to height of the cylinder and with end flanges of suitable size, a very near approach is made to the ideal right-angle. With careful design, an angle of from 100 to 120 deg. can be obtained between the wind direction and the direction of the resultant pressure. This fact explains the ability of the Buckau, in spite of the unfavorable influence of the hull, to sail within three points, about 30 deg., of the wind.

The cylinders are rotated through gearing, having a ratio of 6 to 1, and arranged at the upper bearing. Vertical driving-shafts lead down from the gearing to two reversible direct-current shunt-wound 11 kw. 220-volt motors having a speed of 750 r.p.m. placed inside the supporting shafts at deck level. Current is obtained from a generator driven by a 45-hp. two-cylinder Germania-Diesel engine.

The stability of the ship has been greatly increased by the conversion from the old sail plan. While the old rigging weighed 35 tons and had a total height of 25 m. (82.02 ft.) both pivots complete with cylinders weigh about 7 tons and are 15.60 m. (51.18 ft.) high. Since the propulsive effort is dependent on the relationship between peripheral speed and wind speed and since the peripheral speed can be kept constant and never rises above a fixed maximum, the wind pressure on the rotating cylinders can also rise only to a certain value, even if the wind speed itself increases enormously. One can control absolutely the wind pressure on the ship, by rotating the cylinders at a suitable speed, and almost instantaneously. Moreover, the resistance of the stationary rotor is low, compared with that of the old rigging with sails stowed. It was established that the resistance of cylindrical bodies of a certain diameter does not increase with increasing wind velocity per unit of superficial area, but that according to the given conditions, a sudden drop in the curve of resistances occurs.

Ease of Control

Control at sea is extraordinarily simple. Only one man is needed to manage the electric controls of the rotors. Weather or lee helm can be counteracted in the simplest way by merely altering the relative speeds of the rotors. The ship can be helped in going about by reversing the direction of rotation of the forward or after cylinder. The trials have shown that the ship is not brought up during this maneuver, but carried on through the wind's eye like a yacht. By reversing both cylinders, it is possible to move full-speed astern. Due to the duplicated transmission, the driving gear is extremely reliable. Getting under way is also rapidly carried out. The operation corresponding with setting or stowing sail does not take any length of time, but can be carried out in a few seconds. It is no longer necessary to keep a careful eye on the barometer and weather signs, so as to prepare ahead for changes of weather. The mariner is able instantaneously to adjust his vessel to any sudden change. Even considerable changes in the direction of the wind need not be taken into account, as the rotors need no modification to meet them. It is only necessary to reverse the rotors when the wind comes on the other side of the ship. Apart from slight variations in their speed of rotation, to meet considerable changes of wind speed, the rotors require practically no attention.

I have always been of the opinion that the new system would never replace the modern steamer or motorship, but that it would have a definite value as an auxiliary to the highly developed engine for ship propulsion, by utilizing to the full the available wind-power and that it would thus effect great economies in fuel consumption.—*Engineering* (London).

VALUE OF 1924 FARM PRODUCTS

Crop production in 1924 had a farm value of $11,404,000,000, compared with $10,401,000,000 in 1923; but of this value some $4,951,000,000 worth of crops was fed to live stock, whereas in 1923 the value of crops fed to live stock was $4,286,000,000. Live stock and live stock products in 1924 are given a farm value of $5,951,000,000, compared with $6,233,000,000 in the preceding year, nearly all animal products having decreased in value. The Department of Agriculture points out that the gross value of either crops or animal products last year was exceeded only in the years 1917 and 1920 inclusive when production was greatly increased to cope with conditions in this Country and abroad.

The value of the cereal crops in 1924 was $5,220,000,000, or 45.8 per cent of the total of all crops, as compared with $4,138,000,000 in 1923, or 39.8 per cent of the value of all crops in that year. Every cereal crop increased in value last year. The value of the corn crop in this Country last year is placed by the Department of Agriculture at $2,890,000,000, as compared with $2,538,000,000 in 1923; wheat, $1,131,000,000, compared with $743,000,000; and oats, $799,000,000, compared with $554,000,000. The 1924 cotton crop, including lint and seed, is valued at $1,701,000,000, compared with $1,657,000,000 in 1923. This increased value was due to larger production, as the average price per pound of cotton lint was lower than for the preceding year. Hay and forage crops are given a value of $1,733,000,000, compared with $1,619,000,000 in 1923; the fruit crops, $626,000,000, compared with $642,000,000; vegetables, $1,018,000,000, compared with $1,169,000,000. Nearly all animal products declined in value as compared with 1923, the value of dairy products being $2,586,000,000, against $2,652,000,000 the preceding year; animals raised, $2,267,000,000 compared with $2,440,000,000; and poultry products $994,000,000, compared with $1,038,000,000.—*Economic World*.

CONGESTED IMPOTENCE

The twentieth century has introduced new means and methods which, unguided, bid fair to reduce the large concentrations of population to a condition of congested impotence. The electric power machine, the motor car, the telephone and wireless communication may indeed for a time add to the mass of people who can be kept living and moving in a single agglomeration before congestion reaches the point where the mass must congeal and become stationary.

Today power can be taken hundreds of miles to the factory, and tomorrow the workman will be able, if he wishes, to live on his farm and go by electric train or motor car to his work at any factory within 10 or 20 miles. These new facilities, although adding to the congestion existing at present, are all increasing our power to cope with the difficulty of living and transacting business in the great city.—Dr. Raymond Unwin.

When Does a Motor Truck Become Obsolete?

By F. W. DAVIS[1] METROPOLITAN SECTION PAPER

THE discussion of Mr. Davis's paper was entirely oral at the time of the meeting and the stenographic report has been submitted to those who took part for correction. An abstract of the paper, as published in THE JOURNAL for December, 1924, is printed below so that the reader of the discussion may have an understanding of references made by the speakers to statements contained in the paper.

ABSTRACT

IS obsolescence merely a question of age, or does the maintenance a motor truck receives play an important part in determining its life span? The author undertakes to answer this question by citing numerous references to articles on this subject and by discussing the various factors that make for obsolescence, inadaptability and uselessness.

The original purchase price is settled by the personal judgment of the buyer but, as soon as operation begins, maintenance must begin also, for an idle truck earns no money. As the range of operation may extend from complete idleness to continuous 24-hr. service, so maintenance may vary from efficient supervision to ill-advised mechanical attention.

Many motor trucks of the vintage of 1910 are still in service and many old trucks show an ability to perform their work equal to that of the new ones. Locomotives are sent to the shop for general repairs after they have covered a certain mileage but the cost of the repairs varies with (*a*) the time and age, (*b*) the number of starts and stops, (*c*) the terminal service, (*d*) the road curvature and grades and (*e*) the distance covered.

The fundamental reasons that the subject of depreciation is not better understood are the lack of uniform cost-keeping and the youth of the industry. Depreciation is produced through the tendency to become obsolete, inadequate or useless. A distinction must be made between the natural and the operating life; the former depends upon the three factors given above, whereas the operating life depends on the amount of use the truck receives before it becomes worn out. The most readily adaptable and most widely used method of applying depreciation is the so-called straight-line system. This system does not correspond to either the natural or the operating life but is an arbitrary figure. The rate of depreciation depends upon the first cost, the interest rate compounded, the life of the equipment and the scrap value. Many trucks continue to operate beyond the period of depreciation; when they do, the interest on the sinking fund will help to defray the repair and overhauling charges. When a truck becomes old, the securing of spare parts becomes very important and failure to obtain them will greatly increase the expense of maintenance.

Sometimes, because of poor design or lack of adaptability to the work, a truck becomes inadequate to perform the service required. Expensive changes are then necessary to increase the adaptability by improving the loading and unloading facilities, the ability to meet road conditions, the operating convenience and the protection of the driver.

Uselessness seldom applies to a motor truck that becomes useless only when the service for which it was intended is no longer required. In some lines the advertising value of vehicles is important; it pays to cater to the wishes of the public in the matter of style, appearance, color schemes and the like. Interchangeability of units will assist in prolonging the operation of motor trucks, and the standardization of mountings, accessories and control location is the answer to the situation produced by orphan trucks and the lack of spare parts. The time to determine the fitness of a motor truck for continuing service is immediately before an expensive overhauling. Each case must be judged on its merits. As the future promises no radical changes in design or in operating economy, the items of supervision and maintenance will continue to be the controlling factors in determining the time at which motor trucks should be retired.

THE DISCUSSION

JOHN MCLACHLAN[2]:—I think we all are in accord with the sentiments expressed by Mr. Davis as to the difficulty of arriving at a formula to determine when to retire a truck. It is a problem we have been studying for many years. Regardless of the effort made to keep accurate costs, we are confronted by the obstacle of changes in design. After studying the maintenance of a fleet for 4 or 5 years, along comes a change in design. Realizing that the advance in motor-vehicle design points to a lower operating cost than that of the old truck, nothing remains for us to do but to purchase the new truck. That is evidently the answer to the problem.

In the fourth paragraph of Mr. Davis's paper he touches upon the aging of motor trucks bringing about the failure of non-wearing parts, the increased difficulty in obtaining spare parts and the decrease in productiveness due to forced repairs. The cost of operation increases and the productiveness of the vehicle decreases. This fluctuation should not become evident during the early life of the vehicle but the cost will mount rapidly as the vehicle approaches the end of its economic life.

To determine just what value was contained in the remarks made by Mr. Davis, I had a few figures set out this morning from what we consider very accurate records on our own equipment, taking the operating expenses of 10 2-ton trucks and 10 5-ton trucks, covering a period of 8 years as compared with a 4-year life of two trucks. These figures I will ask Mr. Glynn, the engineer of our department, to give you. I do not believe they will show any possible time to retire the truck but they will provide a little food for thought to users of trucks.

F. K. GLYNN[3]:—We shall consider the 2-ton chassis, as we have had more than 10 in service for 8 full years. The chassis cost, delivered, was $2,700. Operating expenses for 8 years for one chassis, averaged from these

[1] M.S.A.E.—Consulting engineer, Waltham, Mass.

[2] M.S.A.E.—Supervisor of motor vehicles, New York Telephone Co., Long Island City, N. Y.

[3] M.S.A.E.—Engineer of motor vehicles, New York Telephone Co., New York City.

10 chassis, amounted to $12,035, or a total cost of $14,735 for one chassis operated 8 years.

Considering two chassis, each operated 4 years, the first cost of the two chassis would be $5,400. The operating expenses would be twice the first 4 years' operating expenses found in the study of the 8-year-old chassis, or $9,476, making a total of $14,876 as against the previous total of $14,735. But the chassis operated for 8 years would be sold at the end of its life, together with the body, and we could not hope to receive more than $300 salvage, which would reduce the net cost to $14,435. The first of the 4-year chassis would probably be sold without the body, for the bodies which we construct will last at least 8 years and prove useful in telephone work. We would allow $450 as the selling price for the 4-year-old chassis. Then we would sell the second chassis, after having operated it the next 4 years, together with the body, at an approximate figure of $600, making a total salvage in the second case of $1,050, bringing the net cost down to $13,826 as against $14,435.

Mr. Chairman, do you believe that these detailed data are of sufficient interest to take the time it requires to give them?

CHAIRMAN A. F. MASURY:—I think so. I believe the figures, as given, indicate that perhaps the overhauling of these trucks improved them and therefore they operate more cheaply than before overhauling. Perhaps they should have been better at the start. The thing that looks interesting at the minute is that the original cost is so small as compared with the operating cost and that the value of the truck should be higher.

MR. GLYNN:—My figures are not going to line up with what Mr. Masury has just said. Regarding the body, which is a special type of construction body, the only difference in cost in the one system over the other would be the slight additional expense for removal of the body and its re-installation on the second chassis. The days idle in the repair shop for a chassis operated 8 years amount to 190 days. For one operated 4 years they amount to 69 days. Multiplying that by 2 trucks gives 138 days, a saving of 52 days. In our business, if a truck goes out of commission, we have from 10 to 15 men idle until we provide for the situation. We must hire a truck or provide a spare vehicle to keep the other workers busy. Either way, a fair method of arriving at the expense of this spare truck is to subtract the average operating cost per day of use of our truck from the amount paid to the truckman for the hire of a truck. This I have figured at $10 per day for the 52 days or $520, representing the additional days idle, and must be added to the costs on the 8-year chassis, bringing the total figures for the one chassis operated 8 years to $14,955, as compared with $13,851 for operating two chassis 4 years each.

Fatigue of metals will certainly occur during the life of the 8-year chassis but probably will not be encountered in a chassis operated for 4 years. However, in our service the winch equipment takes fully as much toll out of a chassis and the non-wearing parts as road-running does.

The mileage for the chassis operated 8 years amounts to but 58,145 miles, because of the extra days out of service in repair, while in the first 4-year period we were able to operate the chassis 30,125 miles, multiplying by 2 trucks, we have 60,250 miles against the 58,145 miles.

To go a step further, operating one chassis 8 years, we cover a mileage of 58,145 at a total repair cost of $6,627. The first 4 years' average mileage was 30,125, with a total repair expense of $1,956. During the next 4 years the chassis covered 28,020 miles, but the repair expense more than doubled, amounting to $4,651. The total operating expense for 8 years was $12,035. For the first 4 years it was but $4,738 against $7,296 for the second 4 years. I think that answers your point, Mr. Masury.

CHAIRMAN MASURY:—It certainly does. It is alarming.

MR. GLYNN:—I have similar figures on 10 5-ton trucks which reveal this same condition. Operating for 8 years, the average chassis covered 58,897 miles, with a total average repair cost of $9,692. During the first 4 years of operation, the chassis covered 30,532 miles at a repair cost of $3,000. During the second 4 years the chassis operated 28,364 miles and the repair cost jumped from $3,000 to $6,692, or more than double. Our total operating cost for a chassis for the 8 years was $19,526; while for the first 4 years the cost was $7,620 and for the second 4 years it was $11,916. The number of days out of service for repairs over the 8-year period was 224, while only 78 of the 224 idle days occurred in the first 4 years. The sad thing about these figures is that it took 8 years to find this out.

CHAIRMAN MASURY:—I will have to correct my statement about figures, because they certainly seem to mean something in this case. Perhaps they mean that the trucks have operated too long or not long enough.

F. W. DAVIS:—I have endeavored in this paper tonight to deal more with the fundamentals of the subject than to introduce evidence, because evidence can be introduced on both sides and it is easy to use figures to show almost anything. Consequently I am not going to answer Mr. Glynn's figures, because I cannot analyze them at this time. The figures for the 5-ton trucks, which I can keep in mind somewhat, do show a greatly increased cost during the latter 4 years of operation of the trucks, and that bears out one of the points made here, that eventually the time comes when the operating cost goes up. The cost does increase with age and the number of lost days increases with age. The figures given have borne it out, although I am not inclined to over-emphasize any single piece of evidence.

MR. GLYNN:—The operating expense covers the gas, oil, replacement of appurtenances, repairs and miscellaneous items. It does not cover chauffeuring, garaging nor depreciation.

F. J. SCARR[4]:—A definite, uniform policy of depreciation for all classes of trucking business is impracticable and uneconomical. The man in a contracting business should not depreciate his trucks on the same time basis as the man who operates a truck a few miles a day and perhaps only 1 or 2 days a week. They are entirely different problems. Each fleet must be considered upon its own operating conditions. The depreciation period should equal the average economic life of each fleet as nearly as possible.

The economical operation of a fleet of motor vehicles is based upon four points. These are, in the order they must assume in the operation of a fleet, (*a*) selection of the proper vehicle, (*b*) proper inspection to keep it on the road for the longest period possible between overhauls, (*c*) efficient, economical overhaul when overhaul becomes necessary and (*d*) the question before us tonight, retirement of the vehicle at the end of its economical life.

The ideal method of determining depreciation is that book depreciation should equal physical depreciation.

[4] A.S.A.E.—Representative of operating committee B, eastern region, Association of Railway Executives, New York City.

In actual practice that is impossible but the nearer we can get to it the nearer we approach efficiency and economical operation. The whole idea, if my studies serve me correctly, in keeping costs and in setting aside reserves for repairs when they become necessary, is that the repairs or costs should be spread as nearly uniformly as possible over the entire period of the vehicle's operation.

Patrick Henry said in a famous speech, "I have no means of judging of the future save by the past." Believing in that thoroughly, I have taken every occasion to delve into the past. My business has been the operation of motor vehicles and my interest has been in studying their costs and their economical operation. The thing that has stared me in the face on every occasion has been that repair-cost curve mounting higher and higher as the vehicle passed into its later stages of life. The thought occurred to me 3 or 4 years ago that this curve should be cut-off at some period, if we were to enjoy economical operation of our fleet. Where that point is, I am not prepared to state definitely, but if we continue our studies we can reach some conclusion.

My one idea in presenting the formula referred to by the speaker, whether it is operative or not, is simply this: The period during which the greatest expenditure of money for repairs occurs is the overhaul period, therefore it is necessary to take the period just prior to overhaul and figure out a simple arithmetical problem, which is this: We have a vehicle on which we are about to expend a large sum of money; shall we make this expenditure and continue that vehicle in service until its next period of great expenditure, its next overhaul, or shall we retire it and install a new vehicle?

First, make a careful study of the average costs of your fleet of vehicles, classified according to type, capacity and operating conditions. Next, consider the particular vehicle involved and what its past record has been, and from the operating costs estimate what its future costs will be, including the expenditure for the needed overhaul, until the next overhaul period. That gives one figure. Then set beside that figure the estimated cost of a new vehicle operating over the same period and choose the one that costs you less.

MR. DAVIS:—Mr. Scarr did a great service in his article in *Motor Transport*[5] by starting this discussion and giving us something to work on. The only point that he and I disagree on and one that I am still not at all convinced about, is his policy of figuring depreciation; books must be closed at the end of the year. Tax returns and accounting requirements dictate this. If you are not able to arrive at the method of book depreciation until the end of the life of the vehicle, what are you going to do? Will you plead with the Government that you either overstated or understated the depreciation? It is simply a question of whether you should figure depreciation as a book item solely or should figure it on mechanical depreciation. The two should not be confused.

R. E. PLIMPTON[6]:—Mr. Davis has referred to a paper that I gave last February before the Metropolitan Section. At that time, I called upon a number of persons and obtained figures that were presented in the paper[7]. The figures, in actual dollars, showed that the maintenance costs of these companies were not increasing. Perhaps they were able to improve their maintenance methods or to buy supplies more cheaply, but it seems remarkable that costs kept coming down in spite of the rather rapid change in the value of the dollar. Such changes in the purchasing power of money are not always considered in comparing operating costs from year to year. They should be, however, and were in the paper just mentioned.

In the paper that Mr. Davis has given he comments on the poor economy of elaborate overhauls. In motorbus work, which is the line I have been following most closely for the last 2 or 3 years, that should not apply. It is a question of economy in the end, but I cannot see why an elaborate overhaul is wrong in practice. If regular overhauling is not provided for, the tendency is to decide that the units will be taken care of when they need it but the result is that the work is never done. In the smaller installations of only four or five vehicles, when I go to see them early in the morning, especially in the winter, I often find that the owners and executives have been up the night before. Why? Because they have been working on this basis of deferred maintenance or postponed overhauls. The only way to get around this is to do the overhauling regularly. It may be expensive but it will be more expensive in actual dollars and in loss of goodwill to do any other way.

MR. DAVIS:—The point that I tried to make in the paper was the poor economy of the practice of excessive maintenance followed by some companies. For example, one organization regrinds cylinders and crankshafts, replaces all the ball bearings in the axle and does other expensive operations of that kind every year. Now, we know that a cylinder block will stand only a very few regrindings and when a crankshaft is reground several times the strength is seriously reduced and replacement bearings are not obtainable. I have seen cases of excessive overhauling carried to an extreme that was absurd, but I agree that periodical and complete overhaulings are desirable.

M. C. HORINE[8]:—I am in full agreement with Mr. Davis's opinions concerning the importance of keeping truck users informed as to improvements that are made in the product to reduce the cost of maintenance. It would be a splendid thing if the manufacturers would all do more in the way of circulating service data. Another important thing often overlooked is to give the truck owner access to a record of what has been put into a truck. It is the duty of the manufacturer to make available to the purchaser of a truck information as to the possibility of improving his vehicle by the addition or substitution of improved parts that are interchangeable with the old ones.

A new development that will, I believe, in the future, considerably change the conditions from which the New York Telephone Co. and others have suffered is the flat-rate service-system. The flat-rate system is new but it is hardly experimental. Its adoption will take time but it is certainly coming. It is a system of maintenance and repair in the motor-truck service-stations by standardized methods and at standardized prices and it will go a long way toward enabling the truck user to foresee maintenance costs, as he has never been able to do in the past.

In reviewing the telephone company's figures it should be borne in mind that manufacturers are building better trucks now than they built 8 years ago, and that if the company replaced a truck after 4 years of operation the results would be even better in the second 4 years than they were in the first 4, because the trucks would have been improved in that time.

[5] See *Motor Transport*, Nov. 1, 1923, p. 215.
[6] M.S.A.E.—Associate editor *Bus Transportation*, New York City.
[7] See THE JOURNAL, May, 1924, p. 539.
[8] Sales engineer, International Motor Co., New York City.

The Brains of Production

By C. B. Gordy[1]

Detroit Section Paper

ABSTRACT

MANAGEMENT of a production department, like the controlling of troopships during the war, depends for its success upon cooperation and coordination. As various parts of the human brain have definite functions, such as seeing, hearing and the like, so the various parts of the production brain may be said to comprise planning, purchasing, maintenance and sales, each of which has developed a technique of its own.

Formerly, the planning of work was left to the foreman and the workers, but modern industrial operations have become so complex that devices for aiding in their control have become imperative. Inasmuch as American industry will probably operate in a buyer's market for some time to come, to overcome sales resistance, wastes of every kind should be prevented.

Within recent years, two things have directed attention to the importance of efficient management: the pioneer work of F. W. Taylor and the Hoover report on Waste in Industry. Taylor's analysis divided operations into planning and performing.

Efficient production requires careful pre-planning and efficient selection and use of equipment. Quantity and standardization, while simplifying some aspects of the problem, have complicated others, for, with large volume, special and duplicate machines must be arranged in lines, each devoted to the production of a single part.

Efficient use of equipment depends upon the maintenance of the equipment in perfect operating condition, the proper adjustment of the machines in regard to speed, feed and the like and the determination of the best methods of operation. When changes are made by the engineering department, the effect of each change should be investigated and the necessary adjustments made by the planning department.

Preliminary to production must come a determination of the number of units to be produced. This estimate is usually made by the sales department; but seldom is scientific management applied to the sales department to the same extent that it is to the production department. Sales analysis, however, is continually receiving greater attention, and some companies are now able to sell within 2 per cent of their original sales estimate.

After a manufacturing program has been adopted, the planning department determines the required numbers of parts to be produced and establishes flow lines for their manufacture. In order that the flow may not be interrupted, provision must be made for maintaining banks of raw material in front of each line and of finished stock at the ends. Minor parts, of some of which a month's quota can be produced in a few hours, are handled in a miscellaneous department.

Adequate functioning of the planning department depends upon close coordination with other departments, particularly the purchasing department, which must be given sufficient time in which to procure the raw material. Time will be saved if the balance of stock on hand is ignored. Contracts should be let for the new material required and the follow-up department should see to it that deliveries are made on time.

Maintenance is vital. Although seldom so arranged, it should logically come under the supervision of the planning department. Inspection, being of a judicial nature, should be apart from the planning department. Decentralized process inspection, if placed at the end of the lines, will save much handling expense and clerical detail; this also is the logical position for making the count for pay purposes and for keeping the progress records of production.

SEVERAL years ago a story dealing with the direction necessary in convoying troopships to France during the war was published in the *Saturday Evening Post*. The story wrapped the agencies involved in this direction in a cloak of mystery, calling them the Master Naval Intelligence. Convoys picked up the troopships at certain predetermined points, followed for a certain distance, then turned back to repeat the process, leaving the troopships to be guarded by other convoys, as mysteriously directed.

This story summarized the way in which the brains of a production department function. The human brain may be divided into the conscious and the subconscious. Similarly, we may divide the production brain into two parts; the first might be called cooperation; the second, coordination. The parallel is not complete, however, for neither cooperation nor coordination can be classed as subconscious; they are conscious fundamental ideas without which no line of human endeavor can be pressed to a successful conclusion, certainly not in an automobile plant with its volume of work and the minutiæ of detail involved in directing it.

Physiologists have further divided the brain into parts, each with a definite function, such as seeing, hearing and the like. So, the production brain may be divided into parts, such as planning, purchasing, maintenance and sales, each of which, in the hands of trained practitioners, has developed a technique of its own. From the standpoint of production, the clearest picture of the science of coordination and cooperation can be drawn through a description of a planning department.

Planning Department of Recent Origin

Thirty-five years ago we should not have discussed the planning department as such, for none existed. Work was planned, of course, but very differently from the way it is planned in an uptodate plant of today. Planning how the work ought to be done was largely in the hands of the foreman and the workers, chance or the kindness of Providence determining when it would be completed. With the growth of science through research, the operative phases of the business have not been neglected, and old methods are no longer practical.

All this has come about as much through necessity as through conscious effort. Industrial operations have grown increasingly complex, and devices for aiding in their control have become imperative. Pressure of circumstances has, perhaps, been the great formative force. Competent observers anticipate that American industry will be operating in a buyers' market for some years to come, and will continue to meet sales resistance, as has been the condition for several years past.

This means that sales will become more difficult, that wastes of one kind or another must be carefully isolated and remedied, that profits must be found through plant

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economies and not through hitting the high spots in expensive sales campaigns. Our greatly increased productive capacity coupled with a somewhat doubtful market constitutes a real problem and calls for all the genius and imagination that we are capable of bringing to bear on the situation.

Influence of F. W. Taylor

Two things within recent years have directed our attention to the part that management should play in eliminating inefficiency in operation. The first of these was the pioneer work of F. W. Taylor, known as "scientific management." It has always seemed to me that this title, as the designation of his contribution, has been unfortunate, for it gives the idea of something fixed and definite that can be applied to any plant in much the same way that so many cups of sugar are used in making a pudding. His real contribution lies in his demonstrating the fact that scientific analysis can be applied to methods of plant management in the same way that scientific analysis is applied to the development of new facts with regard to electricity.

It was at once evident from Taylor's analysis that the burden of devising the best ways of operating a plant was a responsibility of the management, because the elements involved in the problem were under its control and not under the control of the workers.

Elements of Management

Among these elements are the following:

(1) The raw material used for production; its quality and the regularity of its supply
(2) The equipment for working the raw material
(3) The condition in which the equipment is maintained
(4) The processes through which the raw material must pass to be converted into finished products
(5) The sequence in which parts are sent into the factory
(6) The working conditions under which operators must perform their tasks

Several papers might be prepared in outlining the methods to be followed in scientifically determining the best way of handling each of these elements. Such investigations, however, would involve time, money, genius, technical skill and pecuniary interest in the results. All these requirements are clearly impossible for the individual worker.

The second thing that directed attention to the management's responsibility was the Hoover report on Waste in Industry. This report charged management with more than 50 per cent of all waste.

One of the early moves made by Taylor, as a result of his analysis, was the dividing of operations into two parts, the first consisting of planning, the second, of performing. The first drew all the plans and specifications for the convenience of the second.

Industry has outgrown the situation in which it was possible for one man to carry in his memory everything concerning the business. Production has developed to such a degree that efficient operation depends[3] definitely upon (*a*) the preplanning of the work and (*b*) the efficient selection and use of equipment. So far as equipment is concerned, a modern automobile plant is in an enviable position from the standpoint of other plants whose output is either so small in quantity or so varied in nature that general-purpose machines only can be financed and in that the same conditions prevent the duplication of machines necessary for line production.

[3] See Production Control, by George D. Babcock.

Quantity and Standardization

Two factors, quantity and standardization, have greatly simplified some aspects of planning and, to some extent, have complicated others. With a large volume of product, special and duplicate machines can be arranged in lines, so that each line will turn out a single part. This allows a layout that will utilize space in a factory most economically and will eliminate a vast amount of the handling of material that is necessary when machines are grouped according to type.

It is difficult to determine the volume of output at which such an arrangement becomes possible. The breaking-point in an automobile plant certainly comes when the production is considerably less than 100 cars a day. The limiting factor, of course, is the saving to be effected by the use of additional machines, and can be calculated fairly accurately.

Efficiency in the use of equipment depends upon (*a*) the maintenance of the equipment in perfect operating condition, (*b*) the proper adjustment of the machines as to speed, feed and auxiliary equipment and (*c*) the determination of the best operating methods.

The last factor is affected greatly by the question of quantity. Intensive job-study is expensive but, when the same job is repeated constantly day after day in large quantities, the saving resulting from devising the best way of doing it will quickly pay dividends.

It should be the function of some department in an organization to study constantly the efficient arrangement of the machine equipment. Since the layout of the plant so vitally affects the functioning of the planning department, it ought logically to come under the planning department's jurisdiction. Engineering changes are continually being made, each of which affects the layout to some extent. All changes, consequently, should be investigated by the layout department in order that necessary adjustments can be made. No matter how good a layout may be, inefficiency is bound to creep in unless definite responsibility is placed for its maintenance.

Importance of Preplanning

The brains of production are utilized more, perhaps, in preplanning than anything else, since keeping the production of the factory constant calls for the highest development of cooperation and coordination.

Preplanning consists of:

(1) Determining the number of completed products to be turned out in a certain period
(2) Purchasing raw and semi-finished material to meet the schedule
(3) Developing a method of procedure for supplying material to the manufacturing floors
(4) Determining the schedule quotas of each line and department through an analysis of the number of units to be produced
(5) Developing a system of control that is capable of directing the above elements

The planning department is charged with all these functions, except possibly the first two. In attempting to define such a department, we are confronted with the fact that no uniform practice exists; the term does not mean the same to everyone, and the functions of the department are not always the same. In one case, we find that it is charged with accumulating statistics and devising a budget, reporting directly to the president of

the company; in another, with supervising labor and payrolls, ordinarily left to the accounting division, and with statistics, the layout of machinery, machine standardization costs, and reports of a financial nature, in addition to the functions ordinarily coming under its jurisdiction.

In practice, many reasons for this divergence can be found. The intelligence and wide-awakeness of the organization is bound to affect the amount of detail that a planning department must undertake. Does the factory make what the sales department sells, or does the sales department sell what the factory makes? This will determine the make-up of the activities of planning. Questions, such as standardized or unstandardized product, manufacturing for stock or on order and many others, determine the fate of the planning department. Certain it is, however, that in an automobile plant the planning department should have the controlling voice in deciding what equipment shall be used, how the equipment shall be handled, what shall be the sequence of operations, the control of stores, the method of handling material in the factory and the time required for producing parts of the product, for upon this is based the quota for the line.

Estimate of Production

A preliminary necessary to factory operation is the determination of the number of units to be produced. This is one place in factory operation in which courage and foresight on the part of the higher strata of management are required. Such an estimate ordinarily is made by the sales department and represents a summation of the guesses of the different dealers and distributers. It is surprising that, although precise methods of production planning have been developed, the word planning has been mentioned in sales work only very recently. So-called scientific management, as developed by Taylor, was confined largely to the shop, and only recently has the Taylor Society called attention to the fact that science can be applied to the determination of sales possibilities and have papers been presented on this subject. Yet the accurate forecasting of the demand for a product is the basis of smooth operation. On it depend the policy to be followed in manufacturing, the anticipation of peaks of demand, the economical purchase of materials, the keeping of stocks at the minimum consistent with smooth operation, the ability of the manufacturing department to furnish continuous employment to its employes and many other problems. To operate a plant without a thorough painstaking and scientific analysis of the productivity of a certain territory is equivalent to guessing at the size of the rudder to be used on a transatlantic liner.

A difference exists, of course, between production planning and sales planning. In the former, we are dealing with machines and mechanical equipment, the capacity of which is definitely known; in the latter, no such factors exist. The factory official responsible for making the quota set by the planning department can be relieved of his duties, if he does not accomplish what the planning department knows should be done; but, in sales-work, what should be accomplished is not known with accuracy, and a salesman should not, therefore, be discharged if he fails to do what we do not know that he should do.

Sales Analysis

In an accurate determination of what a plant should sell during a given period lies one of the neglected opportunities of the planning function, a neglect that many automobile plants are beginning to remedy. In the kind of planning just mentioned, an analysis of the product should be made in regard to the strata of consumer demand to be served. The analysis should then show the nature of the territory in regard to prospective sales, or, in other words, its productivity. A current survey of business conditions in each territory will keep the information uptodate. The fact that companies in some lines of work are making sales analyses is ample proof of their practical nature. The Walworth Mfg. Co. has, on the basis of careful sales planning, been able to sell within 2 per cent of what its analysis showed should be sold. Although this accuracy may not be usual, the significant fact is that the quota was determined by analysis and not by guess. As a result of its planning methods, the above-mentioned company knows the variation in demand from month to month. This is as important as is the total demand.

Assuming that the manufacturing program has been determined by models and by the quantity of each model to be made, the planning department separates it into part requirements and, knowing the time required to perform each operation, sets quotas for each line and each department. With the layout arranged so that operations follow in sequence from casting or forging to the finished machine-part, a flow is established; operations become automatic, and the planning department is concerned primarily with keeping enough raw stock before the line, taking enough finished parts out of the line, inspecting them and preparing them for assembling. If quotas that will meet the assembling requirements are once established for each line, the checking-up of actual production with the quota becomes somewhat routine in nature. If anything prevents a line or a department from making its daily quota, and such things have an exasperating way of happening, the executive ability of the man in charge of the planning is called forth. To keep the flow of work constant, quotas must be made; and it is equally true that a line should not be allowed to exceed its quota and pile up completed stock in excess of the bank maintained as insurance against some hold-up or breakdown of machinery. Any other policy will result in an unbalanced condition, excessive funds tied up in stock in process, and excess stock to handle and to occupy valuable space.

Flow Layouts

A prerequisite to the maintenance of this work flow is a layout that will allow the maintenance of banks of raw stock before each line and a bank of finished stock at the end of the line. The closer this bank of completed parts is to the assembling lines the better, for the handling of material will be less complicated and less expensive. A single-story building is, of course, ideal for this purpose.

Even though the layout be such that a single group of machines turns out a single part, many other parts remain, such as stampings and small parts requiring only a few short operations in a miscellaneous department. A month's requirements in some cases may be turned out in a few hours. These parts must be scheduled in such a way that the month's quota of each part will be completed as needed. This may involve a calculation of sequence in scheduling that will result in the least loss of time in changing the machine set-up. In the case of such work as the grinding of raw stock, which must be isolated from the rest of the shop, it would be better to have the operation take place on the receipt of the material prior to storing it, provided ade-

quate facilities are available for storing the parts after grinding.

The specific duties included under the jurisdiction of the planning department vary with the organization and its personnel. Its adequate functioning, however, is dependent upon close coordination with other departments in the plant. This is particularly true with respect to purchasing. The purchasing department must purchase material in the quantities indicated by the manufacturing program and must secure deliveries according to the specifications of the planning department. In carrying out this function, the purchasing agent must have a time distribution that will tell how many days in advance of the completion of a car contracts must be placed for the different classes of material that he buys. Green lumber, for instance, may have to be bought 120 days before a car using this lumber can be completed. This period will include the time that must elapse before the lumber will be received at the plant plus the time required for processing it after it has been received. The processing time includes not only operating times but the time required to move the lumber from one operation to another.

Stock Records

Much lost time and effort will be avoided if the balance of stock on hand is ignored in letting contracts for material. The manufacturing program settles the number of automobiles to be made in a certain period; this, so far as quantities go, is all that the purchasing department need know. Contracts are let covering these quantities of material and the follow-up system should be responsible for seeing that these quantities are delivered in time to meet the requirements of the schedule.

Stock records can be arranged in a manner that will greatly facilitate the follow-up. The issuing of a requisition for each batch of material leaving the storeroom results in too much clerical detail, in the case of the larger part of the material used in assembling an automobile. Material can be charged from the stock records on the basis of the number of cars or units produced during a week or a month, by breaking up this amount of production into the component parts of a complete unit. Certain companies have gone a step farther and disburse stock on the basis of the manufacturing schedule in advance of actual building. This gives the follow-up department a knowledge of any shortage existing at the beginning of the month and gives sufficient time in which to expedite deliveries.

With a purchasing department attuned to the manufacturing program and securing deliveries as specified by the planning department, such costly things as a shut-down because of lack of material can be prevented. This relation of the manufacturing program to the purchasing and the planning control of stores demands the most careful coordination for smooth operation and must be automatic in detail.

Maintenance Department

The maintenance department is a vital factor in maintaining the flow of work through the factory. The successful performance of its duties will result in the planning department's being able to rely on the equipment in setting the line and departmental quotas. Maintenance is so basic to a successful planning department that it ought logically to come under the jurisdiction of that department. Probably only a few organizations are arranged in this way and, indeed, it may not be necessary, provided a spirit of cooperation, which is the essence of the maintenance question, exists, and the maintenance department has the idea well grounded in its make-up that a "stitch in time saves nine." A standing order should require the periodic inspection of all equipment and appliances in the plant, and should extend to window cleaning, conveyors, electric lights and the like.

After a logical layout has been established that allows work to flow through the plant from operation to operation in consecutive order, and after the planning department has properly scheduled the work, some process inspection is necessary. The inspection department, occupying as it does a somewhat judicial position, should be apart from the planning department. But inspection procedure can be performed in a way that will greatly facilitate its work. Placing decentralized process inspection at the end of the lines that make component parts will not only save much handling expense and clerical detail but this is the logical position for making the count for pay purposes and for production progress records. For small parts, such as automatic screw-machine work, central inspection will be more economical.

Several hundred years ago, Rome was saved from one of the many revolts of its populace by the statesman Agrippa. In an oration delivered to the revolters, whom we should call revolutionists today, he used the example of the interdependence of the different organs of the body on one another to show that the different classes of people were necessary and interdependent in the proper functioning of the State. So, in the business of producing an automobile, many different activities are necessary and must be coordinated through proper organization and delegation of authority, in order that the plant may function as a smoothly running machine.

THE DISCUSSION

Question:—Of what importance is flexibility in planning to keep the output in step with the sales, when the sales volume fluctuates with the weather? How is that best provided for?

Prof. C. B. Gordy:—Flexibility is one of the characteristics of planning, whether it is in an automobile plant or in a plant making overshoes. The question of weather is, of course, one of the uncontrollable factors. Sales analysis will hardly ever give the correct answer. The schedule must be arranged so that it can be increased or decreased to correspond with the things over which we have no control. Flexibility is one of the things that are effected by cooperation and coordination. If you have the machinery in the plant lined up like the chairs in an auditorium, and know about what you can turn out, coordination will come with the problem of getting material into the line and through it. If the problem arises, how to increase or decrease the material coming out of the line, inasmuch as the machines are more or less fixed, the question becomes one of getting more or less material to them, or of increasing or reducing the number of operators.

Question:—When should a cumulative record be used, rather than an individual storeroom record? When should a card record be used, rather than a ledger sheet for stock work?

Professor Gordy:—It does not seem essential that any particular record should be kept in the stockroom. Control would come necessarily through the record of stock that is kept in the planning department, or in some other part of the organization. A good many companies have stock records in the control department and in the storeroom, and spend considerable time checking them; finally, they have to count the number of pieces, then

why not get down to one record and keep the record of the stock in the planning department, not in the storeroom?

QUESTION:—Has the Continental Motors Corporation been able to work out any plan that would tend to cut down the waves and variations in its production curve?

G. W. BLACKINTON[3]:—We are in a different position from automobile builders, because the sales planning, as has been said, is done by the man who sells the assembled cars, and our sales planning naturally depends on their sales planning. We do not have the same control over sales planning that a company has which manufactures the car complete. Our planning department, as we refer to it, has to do principally with the production end. Its function is to help absorb the shocks due to fluctuations. For instance, when Hudson makes a change in its production, this changes everything all the way down the line. We simply carry enough material in a department to run the assembling department for 5 or 6 days. In the camshaft department, we carry material for about 15 days. That will be sufficient to absorb the fluctuations that come through inability to have a successful sales plan.

QUESTION:—To what point do you find it economical to store the finished product?

MR. BLACKINTON:—We do not store the finished product that we ourselves manufacture. The only finished material stored is the material bought on the outside. We carry only 2 days' material ahead of assembly at any time, no matter what the condition may be, unless a sudden drop in the schedule of engines, over which we have no control, occurs. We build several different models of engine; and of some things like water-pumps we should probably carry a little more than 1 day's supply. One day's supply based on high production might mean 4 or 5 days' supply based on low production.

R. G. WALDRON[4]:—Has anybody taken any definite steps regarding the systematic handling of machine repair before an actual breakdown occurs? Machine repairmen have vague ideas concerning what might breakdown.

E. L. SHEEHY[5]:—Within the last week or so we have been working on just that proposition. As you know, it is hard to find out in advance what machines will breakdown, and the responsibility cannot be put on anyone that knows more about it than the man who works on them. We have tried to devise a system that will put the responsibility on the operator and on the foreman; and the only way it can be done is to find out what the costs are and work from that end. We have drawn up forms and arranged details for handling that matter by having the foreman make out a request for repairing a machine, turning it over to the foreman of the machine-repair department, assigning the work to a machine repairman, and keeping track of the time and material used. The slip is then passed on to the planning department and a report is made out at the end of the week which shows what machines were repaired, the material and labor cost, and who was responsible. A copy is given to the foreman of each department and also to the superintendent. In that way we hope to be able to reduce the expense.

MR. WALDRON:—The way we have been trying to handle the question at the Hudson plant is to assign to each man a certain group of machines to be looked after. A man is selected who is familiar with the machines of each particular group and knows what wear is most likely to occur; and also he is informed regarding repair parts in store at all times. He furthermore keeps in touch with the planning department so that they will, when necessary, schedule enough material in advance to allow time for making a repair. In one instance, we cut down the number of machine repairmen, in a certain division, from 18 to 9, which shows the reduction in labor on that particular item.

MR. SHEEHY:—I forgot to mention that on this request form we make provision for the man making out the request to state the nature of the repair; consequently, the foreman of the machine-repair department is better able to determine just what man to send to make the repair, so that it will be done quickly and with the least expense.

MR. WALDRON:—By keeping a record of machine repair, by machines, we have found out which machines give the best results over a certain period of time, and that information largely governs the buying of new equipment. As certain machines are very similar in type and equal in capacity, we have no other way of telling which has the greater advantages.

PROFESSOR GORDY:—The automobile industry is an outstanding example of the result of cooperation. A better feeling exists between automobile manufacturers, in spite of severe competition, than between other manufacturers. To have Mr. Waldron tell a group of competitors how he plans to cut down machine-repair expense seems to me to indicate a healthy state of affairs.

[3] M.S.A.E.—Factory manager, Continental Motors Corporation, Detroit.

[4] Planning department, Hudson Motor Car Co., Detroit.

[5] Material superintendent, Continental Motors Corporation, Detroit.

THE MOTORSHIP RABY CASTLE

SINCE 1910, when the first seagoing motorship, the Vulcanus, was fitted with Diesel engines, a continuously increasing proportion of the vessels launched and put into commission each year has been designed to employ this means of propulsion. In view of the fact that the Vulcanus, a small craft of some 1180 tons, was fitted with a Werkspoor four-cycle, single-acting engine of 650 i.hp., it is of interest to see what changes have been made in the design of the engines in the intervening period since they were first put to marine use. Facility for this is afforded by the building and equipping of the motorship Raby Castle. The length overall of the vessel is 412 ft. 9 in., the beam is 52 ft. 3 in., and the molded depth to the shelter deck is 37 ft. The deadweight is 8000 tons, and the ship was designed to have a speed of 11 knots when loaded to its normal capacity and having draft of 25 ft. 6 in.

For its propulsion, one eight-cylinder North Eastern-Werkspoor engine is provided in the engine room amidships. The engine works on the four-stroke cycle and is single-acting. Each of the eight cylinders has a bore of 730 mm. (28¾ in.), while the piston stroke is 1300 mm. (51⅛ in.). They develop a total of 3000 i.hp. at a speed of 92 r.p.m., and drive the vessel through a single shaft.—*Engineering* (London).

Discussion of Papers at the 1925 Annual Meeting

THE discussion of 10 of the 20 papers presented at the 1925 Annual Meeting held at Detroit is printed herewith. The authors were afforded an opportunity to submit written replies to points made in the discussion of their papers. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with the minimum of effort. The other 10 papers were not discussed.

INSTRUMENTS FOR AUTOMOTIVE RESEARCH

BY JOHN A. C. WARNER[1]

ABSTRACT

DUE to tremendous production schedules and rapid advancement, the automotive industry is characterized by its effort to learn the answers to engineering research-problems with utmost dispatch, but the procedure is not without attendant risks. Costly errors have resulted from experimental work improperly planned and executed, from conclusions too quickly drawn and from unjustified interpretation of observed indications. Cut-and-try procedure is resorted to in many instances after hastily applied research methods have failed and, often, the apparently longer course involving systematic research would, in fact, have been fruitful of more prompt and more satisfactory results at a lower net cost.

As originally presented, the paper was accompanied by a demonstration of instruments and apparatus especially adapted to automotive-research problems. These exhibits included

- Bureau of Standards
  - Apparatus for measuring fuel flow by volume
  - Carbon pile telemeter
  - Clearance volume indicator
  - Decelerometer made by the American Instrument Co.
  - Engine indicator made by the American Instrument Co.
  - Pedal pressure indicator
  - Vibrometer
- The Cambridge & Paul Instrument Co. of America, Inc.
  - Electrical apparatus for exhaust gas analysis
- Engineering Division of the Air Service
  - Elverson oscilloscope
  - Farnboro electric engine indicator
- International Motor Co.
  - Riding-qualities accelerometer
- Lubricating Appliance Mfg. Co.
  - Apparatus for determining viscosity and dilution
- Rotostat Instrument Co.
  - Stroboscopic apparatus
- University of Michigan
  - Apparatus for measuring fuel flow by weight
  - Gas analysis apparatus
  - Loudness evaluator developed for the Timken Roller Bearing Co.
  - Modified engine indicator
- Waukesha Motor Co.
  - Phoneloscope for the study of sound, made by H. G. Dorsey

Regarding instrument design and construction, reference is made to the comprehensive but concise rules of Clerk Maxwell, the well-known English scientist, and he is quoted as saying that the fundamental principle is that the instrument should be adapted to the use that is to be made of it and, in particular, that the parts intended to be fixed should not be liable to become displaced; that those which ought to be movable should not stick fast; that parts which have to be observed should not be covered up or kept in the dark; and that pieces intended to have a definite form should not be disfigured by warping, straining, or wearing.

After discussing the subjects of instrumental accuracy, simultaneous indications or records and types of instrument and of apparatus adapted to use in industrial laboratories, the author considers cost factors. Brief descriptions of motion analysis, motion-picture and stroboscopic methods and the study of noise are presented also, and types of devices used in these studies are specified.—[Printed in the April, 1925, issue of THE JOURNAL.]

THE DISCUSSION

W. E. LAY[2]:—Measurement of the fuel consumption of an engine is the determination of a rate of flow expressed as a quantity of fuel used per unit of time. The quantity may be expressed in terms of volume, that is, cubic inches, cubic centimeters, gallons or pints, or it may be expressed in units of weight, as kilograms or pounds. Since the density of a fuel varies somewhat with changes in temperature or in barometric pressure, it is better in general to use units of weight. However, if the specific gravity of the fuel is determined under the conditions of the test, it is a simple matter to convert the units of volume to units of weight.

A variety of devices are available for the measurement of fuel by volume and, generally, they consist of the following parts:

(1) Fuel-supply tank, of any capacity
(2) Valves and connecting tubing
(3) Pipette, stand pipe or measuring tank
(4) Stop-watch

A simple and convenient arrangement is to use, as a measuring tank, a standard pipette such as is used in chemical analysis. This pipette has an enlarged portion integral with small-bore glass-tubes above and below it. An accurately determined volume of liquid is included between two marks, one on the upper and one on the lower tube. The small bore makes it easy to determine

[1] M.S.A.E.—Research manager, Society of Automotive Engineers, Inc., New York City.

[2] M.S.A.E.—Associate professor of mechanical engineering, University of Michigan, Ann Arbor, Mich.

the volume accurately between the two levels. It is convenient to arrange the pipette so that its upper tube or an extension of it will reach above the level of the fuel in the supply tank.

If the valve is allowed to stand open, the engine will receive its fuel from the supply while the pipette will be filled to the level of the fuel in the supply tank and be ready for a run at any time. If the valve is closed, the engine will receive its fuel only from the pipette. The fuel level will descend rapidly in the small tube of the pipette and a stop-watch is started as it passes the mark on the upper tube and stopped as the level passes the mark on the lower tube. The valve is then opened again. The volume of fuel contained between the two marks divided by the time indicated by the stop-watch will give the flow rate. That is

(Volume in Cubic Centimeters $\times$ 0.127) $\div$ Time in Minutes = Fuel Rate in Pints per Hour (1)

Or,

(Volume in Cubic Centimeters $\times$ Specific Gravity of Fuel $\times$ 0.1323) $\div$ Time in Minutes = Fuel Rate in Pounds per Hour (2)

This apparatus is simple, cheap, portable and made up from standard apparatus carried by any chemical supply house. However, it requires considerable attention by the observer at the beginning and end of each run, as the least accurate part of the determination probably is the operation of the stop-watch.

Measuring Consumption by Weight

Measurement of the fuel rate by weight is preferable in some cases. The supply tank can be mounted on a scale and the time in which a given change occurs in the weight of the fuel and the tank can be noted. Electric contacts can be placed on the scale-beam to start and to stop a stop-watch and a revolution counter. This plan has the disadvantage that the sensitivity of the scales is poor, due to the large weight they carry. Since the actual weight of the fuel measured during a run is comparatively small, a small auxiliary tank can be placed on a small-capacity balance, as in Fig. 1, that can be fitted with agate bearings and be read accurately to 0.001 lb. In such an apparatus, any size or type of gasoline supply can be used. The measuring apparatus can be divided into three parts:

(1) The small auxiliary tank mounted on a balance together with the siphon, valves and necessary connecting tubing
(2) The switchboard, shown in Fig. 2, with a battery contactor, an interlocking contactor, a stop-watch, a switch, a push-button, two dry-cells and several lamps
(3) The revolution counter shown in Fig. 3, with a clutch operated by an electromagnet

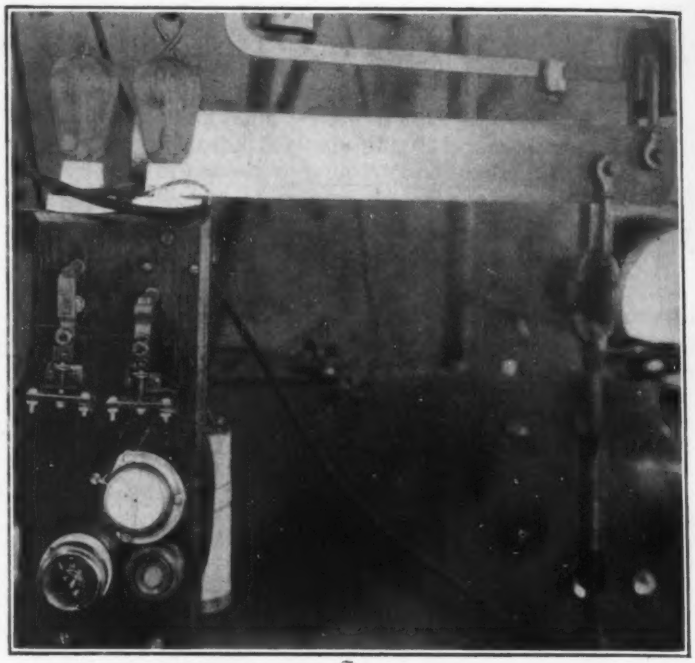

Fig. 2—Two-Circuit Switchboard for Controlling the Apparatus

A Battery Contactor Is Operated from Two Dry-Cells when the Circuit Is Closed Either by the Push-Button or by Mercury-Well Contacts on the Balance-Scale in Fig. 1. With the Switch "On," the Battery Contactor Closes a 220-Volt Circuit through a Revolution Counter on the Engine and Also through an Interlocking Contactor on the Switchboard That Starts a Stop-Watch. The High Resistance of the Filaments of Incandescent Lamps, When Hot, Reduces the Current through an Electromagnet on the Revolution Counter So That No Harm Will Be Done on Long Runs

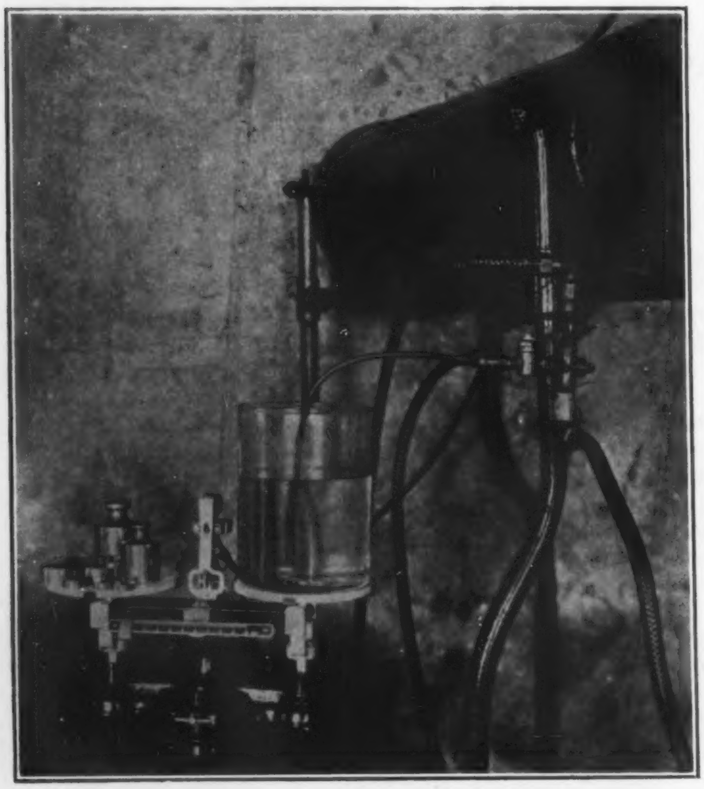

Fig. 1—Apparatus for Measuring Fuel Flow

A Small Auxiliary Tank Is Placed on One Pan of a Delicate Balance-Scale and Partly Filled with Fuel. A Siphon Leads from the Auxiliary Tank to a Shut-Off Valve on the Engine Feed-Pipe and a Second Shut-Off Valve Is Located between the Main Supply Tank and the Engine. By Manipulation of These Valves the Engine Can Take Fuel from the Main Tank or the Auxiliary Tank, or the Auxiliary Tank Can Be Filled from the Main Tank. Movement of the Balance Beam One Way or the Other Closes Electric Circuits that Start or Stop a Stop-Watch and a Revolution Counter

The operation of this device is fairly simple. If the shut-off valve near the supply tank is open, fuel will flow from the supply tank to the engine. If a second valve is opened, it will continue to supply the engine and, in addition, flow through the siphon into the auxiliary chamber on the balance. If the first shut-off valve is closed, then the engine can take fuel only from the auxiliary tank on the balance. It must be noted here that the siphon is established automatically as the auxiliary tank is filled, and a flexible connection is made to the tank which cannot impair the sensitivity of the balance.

The revolution counter and its electromagnetic clutch device is of the type generally furnished with an electric

dynamometer. To make this counter universally adaptable to any type of installation, it is mounted on a tripod and is driven directly by a rubber-hose type of universal coupling. The switchboard has on it two circuits, a 3-volt dry-cell circuit and a 220-volt direct-current circuit. A battery contactor is operated by current from two dry-cells whenever the circuit is closed either by the push-button or by the mercury-well contacts on the balance. If the switch is turned "on," the battery contactor may close the 220-volt circuit through the electromagnet of the revolution counter and also through the interlocking contactor which starts the stop-watch and keeps the circuit of the counter magnet closed. Mazda lamps placed in this circuit allow considerable current to flow as the circuit is first closed, pulling the counter clutch over sharply; but, after the filament is hot, its high resistance cuts down the current through the magnet so that it can do no harm, even for long runs. If the switch is turned to the "off" position, closing the battery circuit causes the interlocking contactor to release, thus breaking the circuit through the counter magnet and stopping the watch.

How the Apparatus Is Operated

The method of operation is as follows: The stop-watch is set back to zero, the counter read and the valves set to fill the tank on the balance until it is just a little heavier than the weights on the other pan. Then the valve in the main supply-line is closed and the switch turned to the "on" position. When enough fuel is used out of the auxiliary tank it comes to a balance, closing the circuit at the mercury-well contacts, and starting the

Fig. 3—Revolution Counter with Clutch Operated by Electromagnet

The Magnet Is Energized To Engage the Clutch with the Engine Shaft and Start the Counter when a Circuit Is Closed Through the Switchboard by Turning the Switch or by the Tipping of the Balance-Scale Beam So That Contact Is Made through a Mercury Well. The Revolution Counter Is Mounted on a Tripod and Is Driven by a Rubber-Hose Type of Universal Coupling

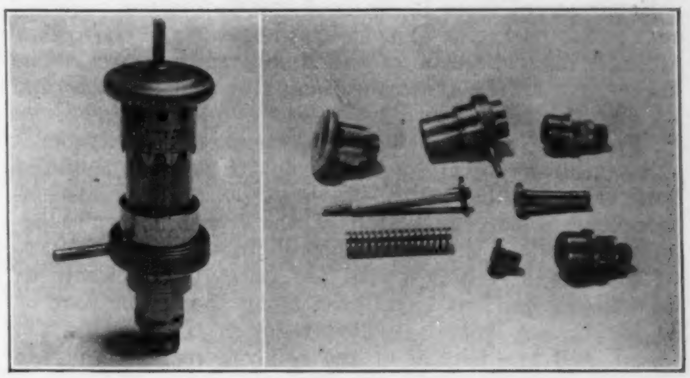

Fig. 4—Liquid-Cooled Okill Indicator for Determining Combustion-Chamber Pressures

This Is Adapted To Be Screwed into a Spark-Plug Hole and To Be Operated Continuously. Its Piston and Cylinder, as Shown at the Right, Are Cooled by Circulating Water or Oil through the Hollow Piston and around the Indicator Cylinder. It Has Been Operated for Hours Without Sticking of the Piston and Has Given Consistent Results

watch and the revolution counter. At any convenient time during the run a weight is removed from the balance pan so that the pan, with the tank, is again too heavy and the switch is turned to "off" position. When enough fuel has been used out, the balance again makes a contact, stopping the watch and the counter. At any convenient time after the run, the weight of fuel used, that is, the weight removed from the balance pan, the time as shown on the stop-watch, and reading of the revolution counter can be observed and recorded.

A rather curious correction must be made when using a siphon in this way. The quantity of fuel actually used is less than the quantity indicated by the balance to the extent of the weight of fuel displaced by that part of the siphon tube which lies between the initial and the final feed levels, the pipe being considered as a solid rod. This error is then proportional to the cross-sectional area of the tube divided by the area of the beaker. The correction ordinarily will be a small fraction of 1 per cent and can be made easily by using a special set of weights, each made heavy to the proper percentage.

This apparatus requires little attention during a run, leaving the observer free to make other necessary observations and adjustments. The recording can be done at any time after the run at the convenience of the observer. The possibility of personal error is reduced to the minimum. The apparatus is accurate enough to give consistent results in a run of less than 2-min. duration, and will even allow one man to make all the adjustments and observations required in a great part of test work.

Pressure Indicator for Long Runs

The Okill indicator is well known to most of us as an instrument for the determination of maximum instantaneous pressures. It operates on the principle of balancing a known steady pressure on the upper side of a piston against the maximum of an unknown fluctuating pressure acting on the lower side of the piston. It is somewhat limited in application as it can show only the maximum pressure reached in any cycle. It is the recommendation of the makers that the instrument be connected with the engine cylinder by a long tube and a shut-off cock, as it will not stand the high temperatures caused by direct attachment and continuous operation. This leaves a rather long constricted passage between the engine cylinder and the piston of the indicator. There is also a chamber under the indicator piston.

Some recent tests in which I was interested required continuous operation of such an indicator and the rather accurate determination of the maximum pressures. The lower part of the indicator, including the cylinder and its piston, was replaced by one of a new design shown in Fig. 4. In the new arrangement the indicator is screwed directly into a spark-plug hole. Its cylinder bore extends flush with the wall of the combustion-chamber so that the piston of the indicator really becomes a part of the combustion-chamber wall.

This piston is hollow and fits its cylinder closely at top and bottom, but is relieved along the major part of its length. A hole is drilled through the wall of the piston near the bottom of the relieved section, and the upper larger section is flattened on two sides. This piston can thus be cooled by water or oil, which passes down through the central tube into the hollow piston. From there it flows through the piston wall into the annular space around the piston and passes upward by the flattened piston into an open tank extending completely around the indicator, and is carried away through the tubing. This indicator has been operated for hours without any trouble due to sticking of the piston and gave very consistent results.

Exhaust-Gas Analysis

G. G. Brown[3]:—An analysis of the exhaust gases leaving a cylinder of an internal-combustion engine is very useful in determining the proportions of the mixture supplied to the cylinder and in studies of combustion. In a brief discussion of this kind it is possible merely to suggest a few of the applications of exhaust-gas analysis and the general method of procedure.

The air-fuel ratio for a fuel composed entirely of carbon and hydrogen, can be determined satisfactorily under ordinary conditions by the following formula[4]:

$$\text{Pounds of Air per Pound of Fuel} = [C \times N_2 \times 0.0764] \div [0.0317\,(CO_2 + CO + CH_4) \times 0.791] \qquad (3)$$

where

C = the percentage of carbon by weight in the fuel
CH_4 = the percentage of methane by volume in the exhaust gas
CO = the percentage of carbon monoxide by volume in the exhaust gas
CO_2 = the percentage of carbon dioxide by volume in the exhaust gas
N_2 = the percentage of nitrogen by volume in the exhaust gas
0.0317 = the weight of carbon in 1 cu. ft. of CH_4, CO or CO_2 under standard conditions
0.0764 = the weight of 1 cu. ft. of air at 60 deg. fahr. and 29.92 in. of mercury under standard conditions
0.7910 = the volume of N_2 in 1 cu. ft. of normal air

Under favorable conditions, when combustion is as complete as possible, this formula can be reduced to a diagram showing air-fuel ratio as a function of the percentage of carbon dioxide, carbon monoxide or oxygen in the exhaust gas. Errors may be introduced by unburned fuel which is not determined by a gas analysis, and by partly oxidized fuel which escapes as aldehydes and similar organic compounds that give the exhaust gas its smarting properties, but these errors are usually small and may be neglected if the foregoing formula is used.

Taking Exhaust-Gas Samples

In determining the air-fuel ratio supplied by the carbureter to the engine, the sample of exhaust gas should be taken from the exhaust pipe between the engine and the muffler at a point not too near the engine, so as to allow the exhaust from the different cylinders to become well mixed. In the determination of charge distribution, if the sample is taken from the manifold as near an exhaust valve as possible, the sample represents the exhaust gas coming from a particular cylinder and not an average of the gases from all of the cylinders. The mixture distribution can be determined satisfactorily by taking samples in this way from each cylinder. A better method is to fit each cylinder with an individual exhaust-pipe that can be combined with the other exhausts in a header, so that mixing is entirely eliminated if the samples are then taken near the exhaust-valves.

Regarding determination of the completeness of combustion, Fieldner and Jones[5] state that the percentage in internal-combustion engines is practically a straight-line function of the carbon-dioxide content of the exhaust gas. Combustion is about 57.5 per cent complete at 7 per cent of carbon dioxide, and is about 97 per cent complete when the exhaust gases contain 14 per cent.

As an analysis of exhaust gas is no better than the sample, the sample should always be taken carefully. Sampling tubes of various kinds have been used by different investigators. The method of inserting a tube into the discharge end of the exhaust pipe is to be condemned absolutely, as the pressure is diminished between exhaust pulsations and air may be drawn into the sampling tube.

The method of tapping a sampling pipe into the exhaust pipe, in much the same way a city gas main is tapped, does not give a representative sample. Most of the gas taken in this way is drawn from outside of the gas stream near the surface of the pipe, and this part of the gas stream may be very different in composition from that of the central part. For the same reason the method of inserting a sampling tube directed against the central part of the gas stream, in a way similar to that used to measure the velocity head in a Pitot tube, may lead to errors.

A satisfactory method is to insert the sampling tube through the entire diameter of the exhaust pipe. That portion of the tube within the pipe is cut longitudinally to present a spoon-shaped opening across the diameter of the exhaust pipe with the opening directed against the stream of exhaust gas. A sample withdrawn from such a tube is fairly representative of the entire stream of gases.

It is advisable to draw a stream of gas continuously from the sampling tube, if necessary, by a water vacuum pump or similar device, and to draw the sample for analysis from this secondary stream. By passing the tube carrying the gas from the sampling tube to the exhausting pump adjacent to the analysis apparatus or sample collector, a fresh sample is assured without the need of pumping out the sample line before each sample is taken.

The sample for analysis can be drawn into the burette of the gas-analysis apparatus and analyzed immediately, or it can be drawn into a sample bottle and analyzed later. Immediate analysis is generally more satisfactory.

Apparatus for Making Analyses

For accurate work, the methane equivalent of the exhaust must be determined. This is best done by a slow-

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[3] Department of chemical engineering, University of Michigan, Ann Arbor, Mich.

[4] See *Industrial and Engineering Chemistry*, July, 1922, p. 594.

[5] See *Industrial and Engineering Chemistry*, July, 1922, p. 596.

combustion pipette incorporated in an improved and modified Orsat apparatus[6]. Such equipment can be built easily as a portable unit and is the best type of equipment for use in a laboratory.

Recorders and indicators of various types as used in powerplants are not suitable for engine work, as they determine only the carbon dioxide and carbon monoxide, or the combustible content, and introduce errors that can be eliminated or at least reduced by the use of the improved Orsat apparatus. For ordinary work, a good simple Orsat apparatus preferably supplied with bubbling pipettes, such as is used around boiler plants, is very satisfactory. For road work, the simple Orsat apparatus is generally preferable to more complete equipment as, usually, under these conditions, no accuracy is to be gained by the use of the more specialized apparatus. Fieldner and Jones describe a simple carbon-dioxide indicator[7] with which they obtained satisfactory results in road tests by determining only the carbon-dioxide content of the exhaust gases.

Checking Accuracy of the Analysis

It is a simple matter to apply a check to the accuracy of sampling and analysis when a hydrocarbon fuel is used, by the following formula:

$$\text{Percentage of Carbon in Fuel} = [600\ (CO_2 + CO + CH_4)] \div [4\ CO_2 + 5\ CO + 8\ CH_4 + H_2 - 2\ O_2 + 0.5284\ N_2] \quad (4)$$

where

CH_4, CO, CO_2, H , N_2 and O_2 represent the respective percentages by volume of these gases in the exhaust gas

$$0.5284 = (2 \times \text{Percentage of } O_2 \text{ in Air by Volume}) \div \text{Percentage of } N_2 \text{ in Air by Volume} \quad (5)$$

If the sample and analysis are correct, the percentage of carbon by weight in the hydrocarbon fuel is given approximately by this formula when normal air containing 20.9 per cent of oxygen by volume is supplied to the carbureter. This formula is exact if all of the fuel is burned, but some of the fuel may pass out unburned with the exhaust. This formula can be used to check the analysis if the carbon-content of the fuel is known, or to determine the carbon-content of the fuel if an accurate analysis is available.

The percentage of carbon dioxide as reported will be lower than the actual percentage unless the water in the burette is acidified with dilute acid or replaced by mercury. Mercury is recommended for accurate work, but acidified water is manipulated more easily and is generally satisfactory. If water alone is used in the burette some of the carbon dioxide dissolves in the water and is lost, as carbon dioxide is very soluble in water. This results in a serious error, as the percentage of carbon dioxide is largely the basis of all computations.

The absorbing solutions must be active, so as to absorb completely the constituents of the gas being analyzed. The caustic solution for carbon dioxide will last a long time. The pyrogallic acid for oxygen must be strongly alkaline and freshly prepared if serious error is to be avoided. If this solution is old it gives off carbon monoxide as the oxygen is absorbed, causing a low reading of oxygen and a high reading of carbon monoxide. Acid cuprous chloride used for absorbing the carbon monoxide is a poor reagent and should always be used in two pipettes, one filled with fresh solution that is used to absorb the last traces of carbon monoxide after the first pipette of used solution has absorbed all that it can[8]. Partial combustion of hydrogen and carbon monoxide over copper oxide, followed by the slow combustion of methane, is probably the most satisfactory method.

New Method of Exhaust-Gas Analysis by Thermal Conductivity

Clarke C. Minter[9]:—Exhaust-gas analysis is now employed rather extensively as a means of studying carburetion and fuel distribution, and is generally recognized as indispensable to automotive research. The usual procedure consists in a simple volumetric determination of the percentage of carbon dioxide in the exhaust, which is a sufficient qualitative indication of the extent of combustion of the fuel.

As incomplete combustion is the general rule today, exhaust gas always contains more or less carbon monoxide and hydrogen, which represent unburned fuel thrown away. Fieldner and Jones[10] have shown that the quantity of carbon monoxide diminishes regularly as the combustion is more complete, and in another paper[11] the same authors state that "in a general way the hydrogen increases with the carbon monoxide and at adjustments for maximum power is approximately 40 per cent of the carbon-monoxide content."

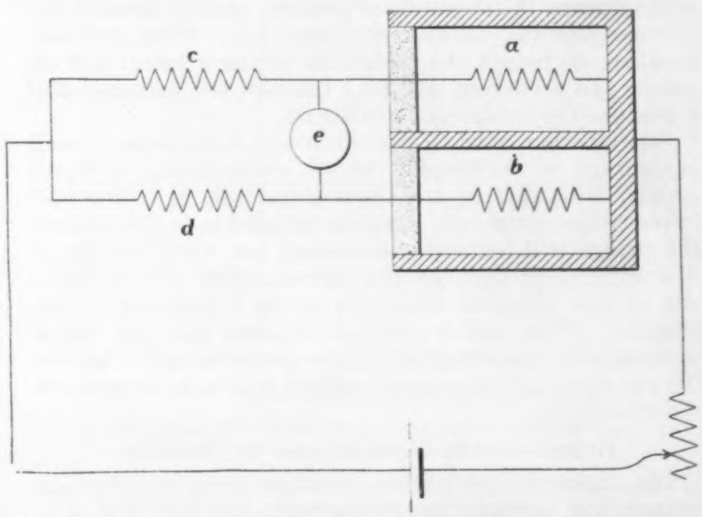

Fig. 5—Diagram of Thermal-Conductivity Measuring Apparatus

Duplicate Conductivity Cells *a* and *b* Contain Platinum Wire Spirals, and Two Manganin Resistance Coils *c* and *d* Are Arranged with Them To Form a Wheatstone Bridge. A Galvanometer *e* Shows the Deflections Due to Opposite Effects from the Flow of Current When the Bridge Is Unbalanced. When Cell *a* Contains Air and Cell *b* Contains a Percentage of Carbon Dioxide, the Resistance of the Spiral in Cell *b* to Passage of the Current Increases and the Bridge Is Unbalanced. When Cell *b* Contains a Small Percentage of Hydrogen, the Resistance of the Spiral Decreases and Direction of the Flow of Current through the Galvanometer Is Reversed. When Cell *b* Contains Exhaust Gas the Deflection of the Galvanometer Will Be the Net Result of the Opposite Effects of Carbon Dioxide and Hydrogen

The statement just quoted led me to believe that the variations in the composition of exhaust gas as the air-fuel ratio is increased would be sufficiently regular to allow the use of thermal-conductivity methods in the analysis of exhaust gas. Assuming the hydrogen to be 40 per cent of the carbon monoxide, a calculation of the thermal conductivity of exhaust gas at various air-fuel ratios will show a perfectly linear relation existing between the two. If, therefore, the thermal conductivity of exhaust gas is a linear function of the air-fuel ratio, a direct comparison of the conductivities of exhaust gas and air should prove to be a valuable practical method for determining the degree of combustion. It has been

[6] See *Chemical and Metallurgical Engineering*, Dec. 10, 1919, p. 734.
[7] See *Industrial and Engineering Chemistry*, July, 1922, p. 597.
[8] See Technical Gas and Fuel Analysis, by A. H. White.
[9] Consulting engineer, New York City.
[10] See *Automotive Industries*, Jan. 4, 1923, p. 18.
[11] See *Journal of the Franklin Institute*, November, 1922, p. 639.

found that a linear relation between conductivity and air-fuel ratio does actually exist, and the mean experimental relation obtained does not differ appreciably from that calculated from Fieldner's data.

The apparatus used in measuring the thermal conductivity was supplied by the Cambridge Instrument Co. and is its standard commercial outfit. The principle of operation can be understood readily from Fig. 5, in which *a* and *b* are two exactly similar conductivity cells, each containing a small spiral of fine platinum wire, and *c* and *d* are two ordinary manganin resistance-coils, the four elements being arranged in the form of a Wheatstone bridge. If cells *a* and *b* both contain air, the two small platinum spirals are heated to the same temperature when the same quantity of current is passed through them, and they will thus have the same resistance and the bridge will be balanced.

If, instead of pure air, cell *b* contains air in which some carbon dioxide is present, the little platinum spiral will increase in temperature because carbon dioxide has a lower thermal conductivity than air. When its temperature increases, the resistance of the *b* spiral will increase and a current will flow through the galvanometer *e* because the bridge is unbalanced.

On the other hand, if the air in cell *b* contains a small percentage of hydrogen, whose conductivity is much greater than that of air, the *b* spiral will be cooled to a lower temperature and, since its resistance is diminished, the bridge will become unbalanced; but the direction of flow of current through the galvanometer will be opposite to that obtained when the air in *b* contains carbon dioxide. When cell *b* contains exhaust gas and cell *a* contains air, the deflection of the galvanometer *e* will be the net result of the opposite effects due to hydrogen and carbon dioxide.

Experimental Method and Its Results

The experimental method consists solely in drawing exhaust gas through the conductivity cell *b* in Fig. 5, a measure of the thermal conductivity being obtained from the galvanometer deflections. At the same time, the percentage of carbon dioxide is determined by an Orsat apparatus.

Fig. 6 shows the set-up used in the investigation. The Orsat apparatus, which is not shown, was connected in the gas line between the engine and the conductivity apparatus by a T-tube. The exhaust was not muffled and the gas, drawn from the engine by a small motor-driven aspirator, was passed through a wash-bottle containing water where, while being cooled to room temperature, it was saturated with water-vapor.

The results of a number of observations are shown in Fig. 7, in which galvanometer deflections are plotted against carbon dioxide percentages. This leaves no doubt about the existence of a regular proportionality between carbon dioxide and hydrogen, even down to the point of complete combustion where the carbon dioxide reaches the maximum percentage of 14.4.

The observations were made during all sorts of variations in atmospheric conditions while the load and speed of the engine were varied over wide limits. The mean experimental relation shown in Fig. 7 should not be taken to mean an average in which experimental error is the only consideration, nor should the deviations from the mean be ascribed wholly to the effects of incomplete vaporization and poor mixing. It will be shown later that these deviations have a very important meaning when they can be interpreted in the light of the views regarding the mechanism of combustion given below. The exact significance of the mean experimental relation will become apparent.

Relation of Carbon Dioxide and Monoxide and Hydrogen

The data obtained so far indicate the existence of a very simple relation between carbon dioxide, carbon monoxide and hydrogen. Since no determinations of carbon monoxide were made in the present investigation,

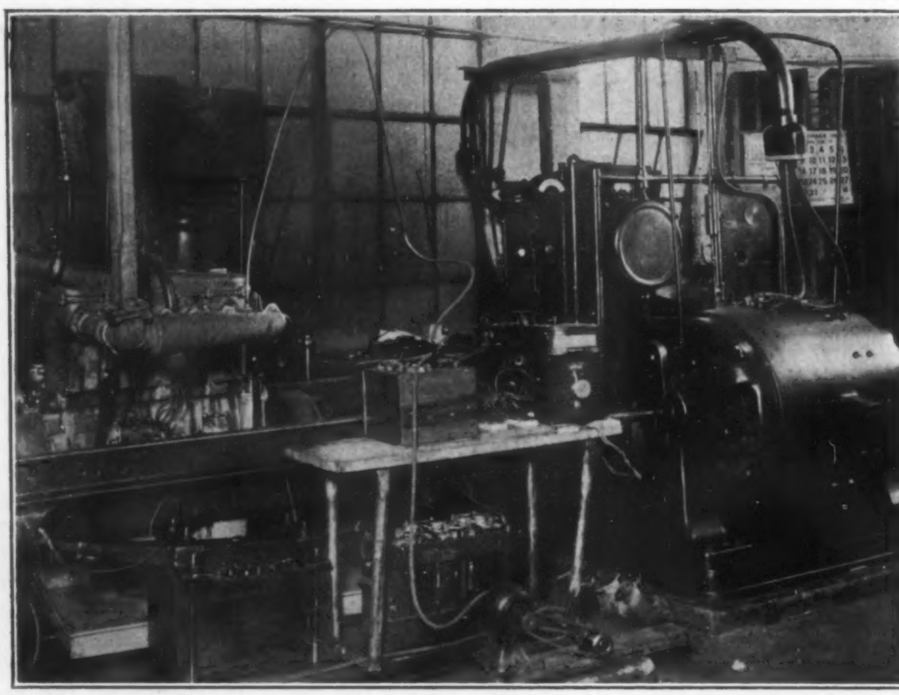

Fig. 6—Temporary Set-Up of Conductivity Apparatus
Exhaust Gas Was Drawn from the Engine by a Motor-Driven Aspirator and Passed through a Wash-Bottle Containing Water, Where It Was Cooled to Room Temperature and Saturated with Water-Vapor. The Air-Fuel Ratio Was Determined by an Orsat Instrument for the Determination of Carbon Dioxide, Which Was Connected in the Gas Line between the Engine and the Conductivity Apparatus but Is Not Shown

the data of Fieldner and Jones were used to obtain a relation between carbon dioxide and carbon monoxide. If their data for these two constituents are plotted, it is found that the mean relation between them can be represented fairly accurately by the slope equation

$$P_w = 20 - 1.39\,P_x \qquad (6)$$

where

P_w = the percentage of carbon monoxide
P_x = the percentage of carbon dioxide.

Fieldner and Jones have found that the percentage of hydrogen is approximately 40 per cent of the carbon monoxide, and this enables us to obtain a mean relation between hydrogen and carbon dioxide, represented by

$$\begin{aligned} P_y &= 0.4\,P_w \qquad (7) \\ &= 0.4\,(20 - 1.39)_x \\ &= 8 - 0.556\,P_x \end{aligned}$$

where

P_y is the percentage of hydrogen.

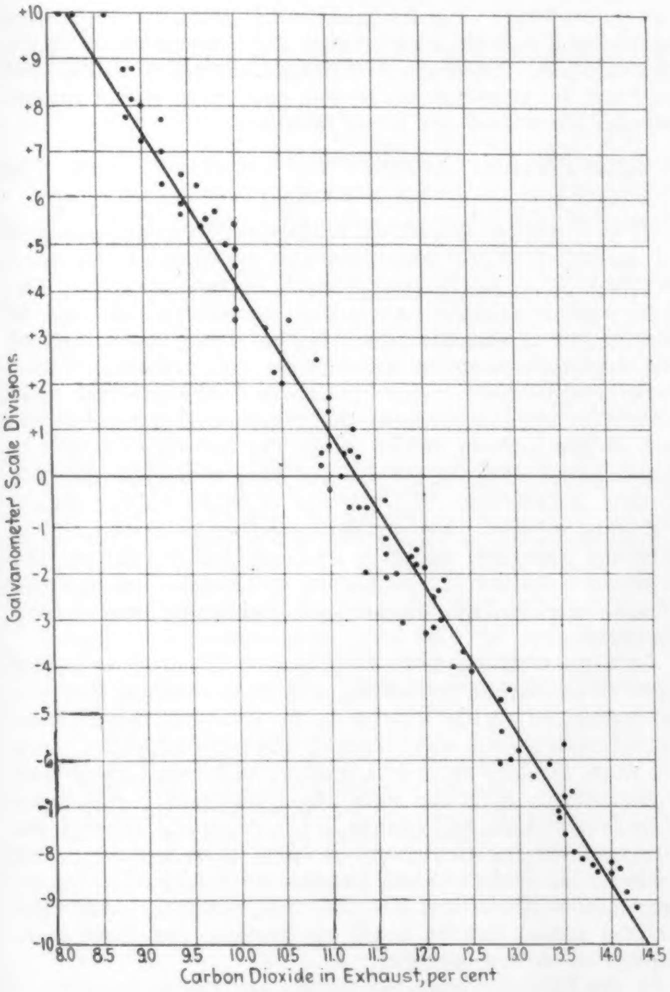

Fig. 7—Plot of a Number of Actual Observations

The Galvanometer Deflections Are Plotted Against Carbon Dioxide and Show the Regular Proportion Existing between Carbon Dioxide and Hydrogen Down to the Point of Complete Combustion, Where the Carbon Dioxide Reaches the Maximum of 14.4 Per Cent. The Observations Were Made during All Sorts of Variations in Atmospheric Conditions and of Load and Speed of the Engine over Wide Limits

The numerical equations above are obtained solely from the data of Fieldner and Jones and it is interesting to note that the mean experimental relation of Fig. 7 can be obtained by calculating the percentages of hydrogen for various percentages of carbon dioxide from the relation shown in Fig. 7 and estimating the net galvanometer deflection from the algebraic sum of the deflections due to hydrogen and carbon dioxide taken sepa-

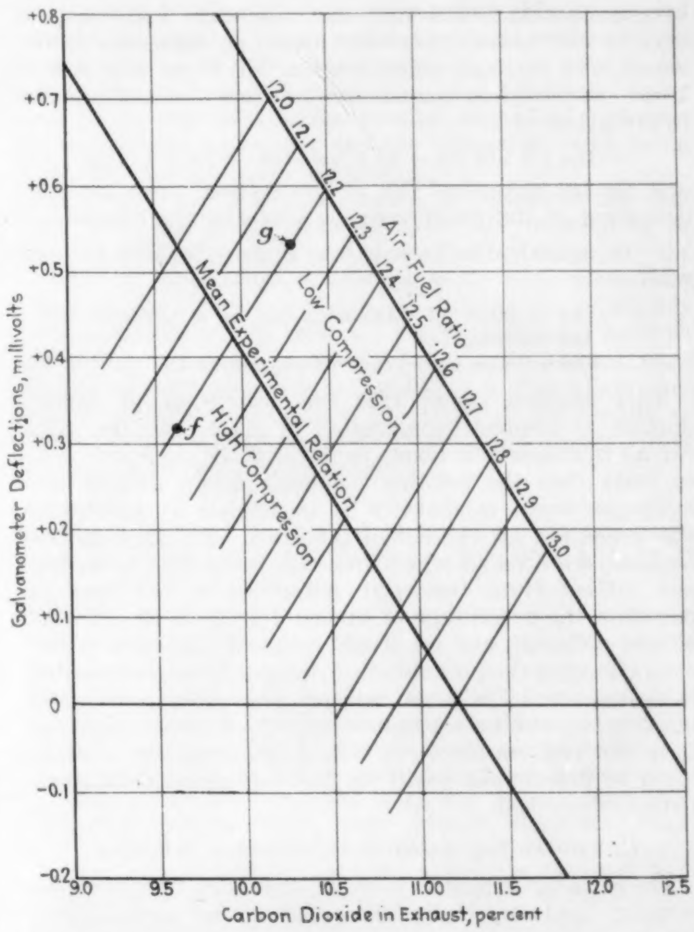

Fig. 8—Variation in Percentage of Carbon Dioxide with Constant Air-Fuel Ratio

With a Galvanometer Deflection of 0.32 Millivolt and Carbon Dioxide Percentage of 9.6, the Point Will Fall at *f*, Indicating an Air-Fuel Ratio of 12.2. Under Different Conditions, a Galvanometer Deflection of 0.53 Millivolts and a Carbon Dioxide Percentage of 10.3, Indicated by the Point *g*, Could Be Produced by the Same Air-Fuel Ratio. A Difference of 0.7 Per Cent between the Two Readings Without Change in the Air-Fuel Ratio Is Thus Indicated. All Points Lying below the Mean Experimental Relation Can Be Interpreted as Indicating Compression Pressures above the Average and All Points above That Line as Indicating less Than Average Compression

rately. The values for the deflections due to the gases separately were obtained from curves supplied by the maker of the conductivity instrument and need not be reproduced in this paper. The point can be brought out, however, by letting 0.47 millivolt be the deflection due to 1 per cent of hydrogen in nitrogen.

Table 1 shows the relation of galvanometer deflections to percentages of carbon dioxide and hydrogen. The net deflections in the last column represent, in effect, the mean relation of Fieldner and Jones' data in terms of thermal-conductivity methods. Comparison of the deflections with the mean experimental relation shown in Fig. 7 shows how close is the agreement between the two sets

TABLE 1—RELATION OF GALVANOMETER DEFLECTIONS TO PERCENTAGES OF CARBON DIOXIDE AND HYDROGEN

Percentages		Deflections, in Millivolts		
Carbon Dioxide	Hydrogen	Carbon Dioxide	Hydrogen	Net
8.00	3.55	—0.54	+1.66	+1.12
9.00	2.99	—0.62	+1.40	+0.78
10.00	2.44	—0.69	+1.14	+0.45
11.00	1.88	—0.77	+0.89	+0.12
12.00	1.37	—0.84	+0.64	—0.20
13.00	0.77	—0.91	+0.37	—0.54
14.00	0.21	—0.98	+0.10	—0.88

of experiments. The fact that the same fuel was not used in both cases apparently makes no difference in the result, and a simple consideration will show why this is true. At complete combustion we have for any paraffin hydrocarbon

$$C_nH_{2n+2} + 1/2\ (3n + 1)\ O_2 = nCO_2 + (n + 1)\ H_2O \quad (8)$$

and the percentage of CO_2 in the exhaust after the condensation of the water-vapor is given by the relation

$$P_x = 100\ P_2\ (2n/3n + 1)/1 - P_2\ (1 - 2n/3n + 1) \quad (9)$$

where

n = the number of carbon atoms in a molecule of the hydrocarbon

P_2 = the volume percentage of oxygen in the air

This relation shows that the percentage of carbon dioxide at complete combustion is practically the same for all hydrocarbons above pentane, C_5H_{12}, and it is safe to state that the relation between carbon dioxide and hydrogen when combustion is incomplete is practically the same for all these hydrocarbons. If other hydrocarbons are used in which the ratio of carbon to hydrogen differs from the ratio obtaining in the case of paraffins, the percentage of carbon dioxide in the exhaust will be different, and we should naturally expect a different ratio of carbon dioxide to hydrogen when combustion is incomplete. The mean relation yielded by a fuel containing benzene or alcohol would be somewhat different from the relation shown in Fig. 7, although the relation could be determined easily by the experimental methods already described.

Chemical Equilibrium in Burning Mixture

The striking relations between the constituents of the exhaust, and especially the relation between carbon dioxide and hydrogen, are certainly not due to accident, and the first explanation of the observed regularities that would occur to anyone familiar with the elements of physical chemistry is that some sort of chemical equilibrium exists in the burning mixture. Since the products of the combustion are water-vapor, carbon dioxide, hydrogen and carbon monoxide, the only chemical equilibrium which could be present is that known as the water-gas equilibrium. The equation

$$CO_2 + H_2 \leftrightarrow H_2O + CO \quad (10)$$

shows that, at equilibrium, the rate at which hydrogen reduces carbon dioxide is exactly equal to the rate at which carbon monoxide reduces water.

It is well known that this same equilibrium exists when hydrocarbons are burned with a quantity of oxygen insufficient for complete combustion, the best example being the inner cone of an ordinary Bunsen burner flame. Equilibrium has been shown to exist in the flame and there is no reason that it should not be attained in the internal-combustion engine in which the high pressures would increase the velocity of the reaction. In fact, the probability of the attainment of equilibrium is greater in the engine than in the flame, and in a set of experiments now being carried on it is hoped that this point can be settled by comparing the exhaust from an engine running on city gas with the gas from the inner cone of the flame when the air-fuel ratio is the same in both cases.

Granting the existence of the equilibrium in the cylinder, and it is difficult to understand how the existence can be denied, the subject of exhaust-gas analysis takes on a new meaning. Instead of a simple determination of carbon dioxide, however, it is necessary that at least two of the constituents be known, and it is particularly fortunate that the two constituents which can best be used to throw light on the process taking place in the cylinder, namely carbon dioxide and hydrogen, are those best suited to thermal-conductivity methods. The accuracy with which hydrogen can be determined in the conductivity apparatus is equalled only in the most refined chemical methods of analysis, and the time usually required in the chemical methods precludes their use in automotive laboratories. The conductivity apparatus will give an accurate indication of hydrogen in less than 3 min., which is the average time required for a complete change of gas in the conductivity cell.

The equilibrium constant of the water-gas reaction is usually written

$$K = (H_2O \times CO)/(CO_2 \times H_2) \quad (11)$$

where K is the constant. The numerical value of the constant depends only on the temperature and would have the same value for all air-fuel ratios at the same temperature. It would thus be possible to calculate combustion temperatures from a knowledge of the composition of the exhaust gas. Data are now being obtained with this end in view, by working on the gas engine, in which experimental conditions are more favorable.

Carbon-Dioxide Content Not Constant With the Air-Fuel Ratio

It can now be understood readily why a certain amount of confusion exists regarding the meaning of the usual determination of carbon dioxide in the exhaust. The high-boiling fuels in use today necessitate the use of wet mixtures and the result is that the greater part of the fuel gets into the cylinder in liquid form. Under such conditions it is possible to vary the air-fuel ratio either by keeping constant the pressure of the air at the end of the suction stroke while the quantity of fuel is varied or by varying the air pressure while the quantity of fuel is constant. In this way it is possible to obtain the same air-fuel ratio under a number of conditions of terminal pressure, and it is obvious that the higher the terminal pressure is, the higher will be the temperature of compression, and this means a higher combustion temperature.

At high temperatures, hydrogen is a better reducing agent than carbon monoxide, and it is obvious that the percentage of carbon dioxide in the exhaust, taken alone, cannot give a true indication of the air-fuel ratio, since the same air-fuel ratio can produce different combustion temperatures, with the result that different percentages of carbon dioxide will appear in the exhaust. It is therefore possible for conditions to vary in such a way that the same air-fuel ratio will produce a number of different percentages of carbon dioxide and, similarly, different air-fuel ratios can be made to produce the same percentage of carbon dioxide.

In the light of what has been said, the mean experimental relation of Fig. 7 can be interpreted as indicating the variation of carbon dioxide and hydrogen with air-fuel ratio when the compression is kept constant at some arbitrary average value and the air-fuel ratio is varied by the quantity of fuel drawn in. It could be expressed also as meaning a variation of air-fuel ratio at constant volumetric efficiency. The points which lie to one side or the other of the mean relation can now be used to follow the variations in volumetric efficiency at any particular air-fuel ratio, in addition to furnishing an indication of the ratio.

To explain how the observations can be interpreted, a portion of the mean relation in Fig. 7 is reproduced in Fig. 8, in which lines of equal air-fuel ratio have been

constructed. Suppose that the galvanometer deflection is 0.32 millivolt and the percentage of carbon dioxide is 9.6, then the point will fall at *f*, indicating an air-fuel ratio of 12.2. Under different conditions, a galvanometer deflection of 0.53 and a percentage of 10.3 for carbon dioxide, indicated by the point *g*, could be produced by the same air-fuel ratio. The difference between the two readings is 0.7 per cent of carbon dioxide and the air-fuel ratio has not been changed. We can therefore interpret all points lying below the mean experimental relation as indicating compression pressures higher than the average and all points above the mean as indicating below the average compression.

As an alternative method, instead of determining carbon dioxide, the exhaust gas can be passed through a caustic solution or soda-lime to remove that constituent, and an indication of the percentage of hydrogen can be obtained with the thermal-conductivity apparatus. The galvanometer deflections so obtained can then be plotted against the net deflections and the mean experimental relation is obtained. The same method can be used in determining the air-fuel ratio, the only difference being that in the first case carbon dioxide instead of hydrogen is used to place properly the net deflection, both being necessary for a correct indication.

In conclusion, attention should be called to the fact that while the views outlined above are believed to be fundamentally correct, an exact formulation of the process of combustion cannot be made until more data are obtained; this work is being carried on as rapidly as circumstances will permit. The experimental method, however, can be put to practical use in its present state of development and it is believed that a little experience will enable the investigator to interpret the results of exhaust-gas analysis in terms of manifold design, valve design, valve timing and so forth.

RECENT DEVELOPMENTS IN AIRCRAFT ENGINES

BY L. M. WOOLSON[12]

ABSTRACT

ADVANCES in airplane performance during the last few years may be ascribed mainly to advances in aerodynamics and to improvements in powerplants. The latter have resulted in producing more power for the same weight of engine and smaller overall dimensions for engines of the same power-rating. The accompanying paper describes two engines of 500 and 800 hp. respectively that have been recently developed by the Packard Motor Car Co. for aircraft service. When these engines are compared with previous types they are found to be more compact and to produce more power per pound of weight. When each is operated at its rated speed, the Model 1500 engine develops 100 hp. more than the Liberty while weighing 140 lb. less, and the Model 2500 engine develops 250 hp. more than its predecessor, the Model 2025, with a decrease in weight of 75 lb.

In applying these facts to commercial aviation, these comparative performances mean that the new engines can carry double the pay-load over the same distance or the same pay-load 2¼ times as far as could their progenitors.

These improvements have been made possible largely because of a new type of cylinder construction, original studies with regard to the loads that can be carried by bearings, reduction of the weight of the crankshaft while at the same time strengthening it, and the compacting and lightening of the timing and accessory-drive layout. Other improvements were made in the lubricating system and in the design of the valve-gear and springs.

Nothing was taken for granted and every detail was given the closest scrutiny. It was decided that if a distinct advance in the art was to be made, it could be accomplished only by disregarding precedent and starting at the ground. As a result of investigating the relation of bearing materials to allowable speeds and loads, it was ascertained that failures of aircraft bearings rarely occur because of lack of lubrication or of wear but are caused by fatigue of the babbitt lining produced by minute flexing of the back of the bearing. Tests showed that the limitations of the bearings could be raised provided they could be prevented from flexing under load and ample force-feed lubrication were provided. The *PV* values of the bearing loads adopted, as compared with those of the Liberty engine, are: for the crankpin, 18,520 lb. per sq. in. as against 13,200; for the center bearing, 35,000 as against 22,650; and for the intermediate bearing, 27,000 as against 14,000.

The critical speed of vibration of the Packard crankshaft is 64 per cent higher than that of the Liberty; it is also twice as stiff as well as weighing 30 per cent less, a feature accomplished by the use of journals having comparatively large outside diameters but bored out through their centers.

Novel cylinder construction enables the cylinders to be spaced closely together and the weight of the whole engine to be diminished. Other advantages incorporated into the design include water circulation in close contact with the heated surfaces, the use of a steel cylinder-barrel as a wearing surface that carries the explosion loads down to the crankcase, the locating of the hold-down flange some distance from the end of the cylinder barrel so that the ends of the barrels of the cylinders of the two banks can practically be allowed to touch inside the crankcase and the engine can be run in an inverted position.

Still other features comprise improved types of valve-housing and valve-gear layout; positive cooling of the exhaust-valve by oil pumped through it; a special type of multiple-cluster small-diameter piano-wire valve-spring; simplicity in the grouping of the accessories; a special type of magneto having a single magnetic circuit and two independent electrical circuits, either one of which will fire all 12 cylinders; the possibility of replacing magneto ignition with battery ignition by substituting a generator for the magneto but without other change to the engine or to the wiring between the distributors and the spark-plugs; the use of very short comparatively light rugged slipper-type pistons; and the ability to use either direct drive or gear reductions.

As each improvement in engine design means an immediate improvement in airplane design, recent developments in engine design have already made possible maneuvers that would have been impossible a few years ago. Although experimental work is continually being directed along conventional lines, such as the barrel and cam types of engine and those of the Diesel or the semi-Diesel type, the most important advances, in the opinion of the author, are to be made by conventional 12-cylinder water-cooled engines and by 9-cylinder fixed-radial air-cooled engines.

When the weight of airplane engines is reduced to 1 lb. per hp., as seems likely in the near future, the engine will consume its weight of fuel every 2 hr.

[12] M.S.A.E.—Aeronautical research engineer, Packard Motor Car Co., Detroit.

It is important, therefore, that, as the carrying capacity of the airplane is reduced by the amount of fuel that must be carried, efforts to reduce the fuel consumption should run concurrently with those to improve the engine.—[Printed in the March, 1925, issue of THE JOURNAL.]

THE DISCUSSION

A MEMBER:—Do the steel cylinders require machining after they have been assembled to the aluminum cage on top of the valve-head? Do the valve ports have to be bored after assembling?

L. M. WOOLSON:—The valve ports are not bored, but the valve-seats are formed after they have been assembled. The cylinders are interchangeable, to a large degree, and are frequently interchanged after the valve-seats have been formed. Of course, it is necessary to grind the valves in such cases.

QUESTION:—Are rotary engines obsolete? If so, why?

MR. WOOLSON:—I judge that they are obsolete for the reason that they have been displaced by the fixed radial type, which from every standpoint is superior. With the same size engines, it is possible to secure more useful power from the radial than from the rotary type since the latter consumes considerable power in rotating itself. It is not necessary to rotate the cylinders to cool them. Because of centrifugal forces, it is necessary that the rotary engine should be made of much better material than the fixed radial. For example, the crankcase of the rotary must be machined from a solid billet, whereas the fixed radial employs a cast-aluminum crankcase which is a far more economical manufacturing proposition.

QUESTION:—How is pressure lubrication effected in an inverted engine?

MR. WOOLSON:—So far as the feeding of oil to the bearings is concerned, no change is made in the engine when it is operated upside down, but the draining of the oil from the crankcase is arranged somewhat differently. The cylinder barrels projecting through the crankcase leave a sump into which the oil can drain back; from there it flows by gravity to a manifold and is pumped back into the oil tank in the same way as when right side up. In fact, it is just a matter of draining the different compartments formed by the cylinder barrels projecting through the crankcase, each compartment being limited by the transverse walls of the crankcase, as compared with the single sump in the right-side-up engine. Otherwise, the problem is not different. At the high speeds at which the engines operate, the oil does not know whether the piston is in one position or in the other. The effective acceleration is far greater than that of gravity. No trouble is experienced in getting oil into the cylinders, provided the cylinder barrels project inside the crankcase.

QUESTION:—What is the operating brake mean effective pressure at full load?

MR. WOOLSON:—The mean brake effective pressure was shown clearly in Figs. 2 and 3 of my paper.[13] It is about 140 lb. per sq. in. The operating brake mean-effective pressure, of course, depends on the amount of throttling and is probably about 115 or 120 lb. per sq. in. The fuel consumption is about the same as that of any other aircraft engine: about 0.53 lb. per hp-hr. for the maximum output and 0.47 lb. per hp-hr. for the maximum economy.

QUESTION:—Why are two-cycle engines no longer considered?

MR. WOOLSON:—They are considered very frequently. No two-cycle engine has yet been built, to my knowledge, that has the necessary flexibility for aircraft operation. Many persons appear to think of aircraft engines as suited only for full-throttle operation, but that is not true. It is just as important to have flexibility in an aircraft engine as in an automobile engine. If a two-cycle engine could be built that would throttle, accelerate and operate wide open as well as a four-cycle engine, it would undoubtedly be used to a greater extent. Another important consideration is that of fuel consumption. In the past the two-cycle engine has been notoriously wasteful in fuel consumption. I do not know what the lowest fuel consumption of a two-cycle engine is, but it probably is much higher than that obtained with a four-cycle engine.

QUESTION:—If one primary-winding of the magneto has a dead short-circuit, will that have absolutely no effect on the functioning of the other winding?

MR. WOOLSON:—It depends largely upon where the dead short-circuit is. If the primary winding had absolutely no impedance left, because all the terminals were short-circuited, the external impedance would tend to prevent the choking effect of the short-circuit of the primary. In fact, that is what it is put there for.

I will not say there is no effect at all; but one cannot tell the difference, when the engine is running on the single spark, whether the other primary is merely open or is short-circuited; that is, provided there is impedance in the circuit. If impedance is not in the circuit, the engine will miss badly and may quit.

QUESTION:—What material was used for the valve-seats?

MR. WOOLSON:—The valve-seats are part of the combustion-chamber and are chrome-nickel steel forgings, containing 0.40 per cent of carbon.

QUESTION:—Have you had any trouble with the babbitts getting loose or wearing, in steel-shell babbitted bearings? Does the steel stand-up without being crushed?

MR. WOOLSON:—We have had absolutely no trouble; in fact, the result has been just the reverse. The babbitt will loosen in the bronze, not on account of poor bonding but on account of flexing. The modulus of elasticity of steel is about double that of bronze. A steel shell of a given thickness is as good as bronze shell of considerably greater thickness.

QUESTION:—What are the present disadvantages of the inverted engine? In particular, is much lubrication trouble experienced?

MR. WOOLSON:—We do not know what the present disadvantages are. Much flying has not been done with real inverted engines. This question will probably be settled by flight tests during the coming year; until they have had considerable service, it is impossible to say just what the troubles will be. The lubrication problem is not nearly so difficult as it appears.

QUESTION:—What are the main reasons that the auxiliaries cannot be driven from the propeller end of the crankshaft, to avoid the effects of torsional vibration?

MR. WOOLSON:—It is merely a matter of convenience, or largely such a matter. No reason exists why it cannot be done, but if the gears were attached to the crankshaft at that end, they would have to be very large in diameter. The thrust-bearing must have a large shoulder to rest against; assuming that the timing-gear is at the rear of the thrust-bearing shoulder, it would have to be sufficiently large to pass over this shoulder and, consequently, the crankcase would require a large clearance hole for the mating gears, which would tend to weaken the crankcase at this point.

[13] See THE JOURNAL, March, 1925, p. 298.

No objection to having the gears at the rear end exists, provided the crankshaft is stiff enough; and a stiff crankshaft is not objectionable, especially if it is lighter than the other types.

Limiting Factors of Design

QUESTION:—What are the limiting factors of the maximum-size power-unit other than the cost? Are larger units desirable and why?

MR. WOOLSON:—We do not know of any closely limiting factor. We have designed engines as large as 3500 hp. that weigh less than 1 lb. per hp. It is really a question of demand and of what the airplane builder can use. The reaction now seems to be toward the use of smaller engines in airplanes, even of the load-carrying type, and gearing them down, running high-speed engines with slow-speed propellers. On the other hand, in lighter-than-air operation that does not seem to be the case and a fairly well-defined demand exists for engines of larger size. So far as we are concerned, it is altogether a question of demand. So far as we know today, we could build engines of the conventional type up to 3000 or 4000 hp. without any particular trouble; but no demand for them exists just now.

CHAIRMAN C. L. LAWRANCE[14]:—In the arrangement of the valves, the four exhaust-valves in your engine are in one compartment and the four inlet-valves in another. Do the two valve-stems and guides nearest the port suffer at all or show any greater tendency to wear or to distortion than the other two, because of the exhaust gases passing over them?

MR. WOOLSON:—When we laid out the design we feared that that difficulty would occur, but I cannot say which valves get the hotter. We maintain them all at very low temperatures. There must be some difference but we do not know what it is. There certainly cannot be much difference.

QUESTION:—How is the babbitt held to the steel back?

MR. WOOLSON:—By grooves cut into the steel circumferentially. The babbitt is molded onto the steel by a centrifugal process by a company in Detroit. We have had just 100-per cent satisfaction from the steel-backed bearings.

QUESTION:—Have any tests been made to determine the effect of the oil-cooling of exhaust-valves on the character of the used oil?

MR. WOOLSON:—That was one of the first things we did. The oil people assured us that if the oil did not exceed a temperature of 400 deg. fahr., no trouble would be experienced because of carbonization. As a matter of fact, the oil does not get above about 220 deg. fahr. After running a 50-hr. test on the first engine equipped with this system, we sent samples of the oil to the oil company and they gave us a "clean bill of health." No trouble has been experienced with carbonization. It is merely a question of assuring a rapid flow of oil through the valves. If it is circulated slowly, it will have time to carbonize and to cause trouble.

WHEEL SHIMMYING: ITS CAUSES AND CURE

BY O. M. BURKHARDT[15]

ABSTRACT

SHIMMYING is an oscillating motion produced by repeated impacts or forces in the linkage of a mechanism that lacks stability or has become loose because of wear. Although previously existent in chassis in which the steering gear was imperfect, it has become particularly noticeable since the introduction of low-pressure or balloon tires. But increasing the rigidity means increasing the unsprung weight, which, in turn, means greater impacts, hence, more shimmying. This is apparent in the effect produced by front-wheel brakes. Consequently, as the amount of looseness that can be removed is limited, the periodic forces that cause shimmying must be overcome.

The propensity of low-pressure tires for assuming periodic rebounds when traversing bumpy roads and for causing shimmying and tramping, as well as pitching and bobbing, is illustrated by an example involving the use of springs; and the deduction is made that in order to minimize its ill effects, the kinetic energy stored in the tires must be absorbed. Another example proves that only 76 per cent as much kinetic energy is stored in high-pressure tires as in balloon tires.

Lateral stability in a tire is a very desirable feature. The lack of it in balloon tires has a profound effect on the steering and produces shimmying. Backlash will cause the same result in cars having center-point or near center-point steering.

The use of a dash-pot, which prevents the lateral forces from synchronizing and, therefore, from gaining momentum, and of friction-discs mounted on the king-pin and the knuckle-shaft, to absorb kinetic energy, is recommended as having a beneficial effect. The three remedies for shimmying suggested by the author are:

(1) Design so that no slackness can develop
(2) Design for rigidity
(3) Use effective devices to absorb kinetic energy wherever it is likely to accumulate

[Printed in the February, 1925, issue of THE JOURNAL.]

HOW HARD DOES A CAR STEER?

BY F. F. CHANDLER[16]

ABSTRACT

RELATIVE ease or difficulty of steering has in the past been largely a matter of psychology, of comparison rather than of measurement. One driver may find a car difficult to steer that another finds easy. Safety is the first essential, then comfort. Because the parts used in steering seldom break, present practice is considered safe, but the steering-ratio is very important. A low ratio that produces fast steering-effects may be entirely safe in the hands of a strong, safe, experienced driver, but absolutely unsafe in those of a weaker driver, even though he may be expert. Fatigue, however, will eventually affect the strong as well as the weak driver, so that comfort enters as well as safety.

With a view to eliminating the personal factor and

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[15] M.S.A.E.—Consulting engineer, Pierce-Arrow Motor Car Co., Buffalo.

[16] M.S.A.E.—Chief engineer, Ross Gear & Tool Co., Lafayette, Ind.; trustee, Purdue University, Lafayette, Ind.

determining by exact measurement the steering-effort exerted by a driver and the reactions termed road shock, road fight, shimmying and the like, instruments have been devised to produce a graphical record simultaneously of (*a*) the amount of steering-effort and the reactions at the steering-wheel, and (*b*) the stress imposed upon the drag-link; note is also made whether the steering-effort is to the right or to the left.

The details of construction and operation of these instruments are described and the results of tests made on roads of various types when the car is traveling at various rates of speed are discussed. A study also was made of the comparative effort exerted in making turns to the right and to the left, in suddenly reversing the direction of stress, and of the effect produced by the impact of a wheel's striking the curbstone.

Statements are made that tests show that the drag-link stress of a car not in motion ranges from 400 to 600 lb., that balloon tires require 50 per cent greater steering effort than do high-pressure tires, that in some high-grade popular cars a difference of only a few ounces of steering-effort changes unsatisfactory conditions into very satisfactory results, that differences as great as 450 per cent have been found in the friction of the steering-knuckle thrust-bearings of current models of well-known cars, and that a difference is apparent between the steering-efforts required in cars having and in those not having center-point steering.—[Printed in the February, 1925, issue of THE JOURNAL.]

FRONT-WHEEL SHIMMYING

BY W. R. STRICKLAND[17]

ABSTRACT

ALTHOUGH wheel wabble, even with high-pressure tires, is of ancient origin and the general methods of controlling it have been well understood, its importance among present-day problems is due to the fact that the recognized specific for its treatment, namely, increasing the air-pressure in the tires, has been denied. Shimmying, as generally applied, includes wabble, or the sidewise vibration of the front wheels about the knuckle-pin, and tramping, or the bouncing of the wheels vertically, alternately on the two sides.

In addition to discussing the advantages and disadvantages of the low-pressure tire, the author has enumerated the results of tests, some of which have been obtained from original research work by himself, others from the literature on the subject, with a view to determining whether shimmying is caused by defects in design, and what are the effects when certain modifications are introduced. Among these modifications are the use of moderate pressures and flexibility, wider rims, reversed caster-angle, increased weight on the front wheels, shock-absorbers, and hydraulic dampers on the steering-mechanism, and changes in the geometry of the steering-gear.

The conclusions reached are that the low pressure and the thin side-walls of balloon tires are the chief factors contributing to front-wheel shimmying and that no acceptable changes in chassis design can be made to control it. A perceptible improvement in riding comfort and freedom from shimmying can be obtained, however, by the use of a moderate design of balloon tire, not too thin a side wall, proper width of rim, and medium air-pressure.—[Printed in the February, 1925, issue of THE JOURNAL.]

EFFECTS OF BALLOON TIRES ON CAR DESIGN

BY J. W. WHITE[18]

ABSTRACT

INASMUCH as the use of low-pressure tires has become established, the conditions of car design affected by them are reviewed, particular reference being made to the members of the chassis included under the term unsprung weight, namely, the axles, the wheels and the tires.

Referring to the principles that underlie basic design, the author first investigates the effect on the steering of such changes and compromises from the perfect structure as failure of the king-pin to coincide with the vertical load-plane, the inclination of the king-pin toward the wheel, or the wheel toward the king-pin, or both, and the giving of a toe-in to the front wheels. Further modifications have served to reduce the car shock, to add to the strength of all the parts by increasing the dimensions, to improve the spring-suspension, and to reduce the car weight per passenger. But four things remain to be done, namely, to stop the angular rotation of the axle because of the flexing of the springs, to eliminate backlash in the steering linkage, to construct a positive-steering mechanism that will be absolutely neutral, and to divorce the steering mechanism from all influences except those that occur from the road.

In the opinion of the author, all these objectives can be reached, but then looms prominently the question of lateral stability. This is to be expected unless the width of the rim is increased. In high-pressure tires, the normal ratio of the width of the rim to that of the tire is about 62 per cent, but ratios of from 50 to 55 per cent are common. Lack of lateral stability has amplified the errors of present design until a point has been reached at which shimmying has become prevalent.

By studying the footprints of tires, it is found that the side-slip per revolution is 60 per cent greater with balloon tires than with high-pressure tires. As the forward rake of the king-pin exerts a leverage that tends to turn the wheels still farther in the same direction, these two forces are said to be sufficient to cause shimmying even though the geometry of the steering mechanism were neglected.

The conclusion reached is that, in order to avoid shimmying, all backlash must be taken out of the steering-mechanism, and that, so far as possible, all rake of the king-pin outward leading of the wheels, and toe-in should be eliminated. The introduction of an hydraulic steering-gear is suggested as a means of accomplishing these results.—[Printed in the February, 1925, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN H. W. ALDEN[19]:—I have been driving a car for a year and a half with very low-pressure tires, one of the first sets that the Firestone Company put out. I

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[18] M.S.A.E.—Chief engineer, disc wheel division, Wire Wheel Corporation of America, Buffalo.

[19] M.S.A.E.—Chairman of the board of directors, Timken-Detroit Axle Co., Detroit.

have absolutely cured shimmying on my car, and never have any trouble. Perhaps the real solution for it is that I never drive the car at a speed of more than 45 m.p.h.

H. M. CRANE[20]:—It seems to me that the source of all the trouble at the steering end of a car lies fundamentally in the very insecure connection between the tires and the road. Because of its flexibility, the connection is very insecure even with normal tires. With large balloon tires and extremely low pressures, it becomes very indefinite.

We talk about center-point steering, but do we really know at any time how near the projection of the steering-pivot comes to meeting the center of pressure of the tire on the road? The pressure area is a large area; it is long and fairly wide; it is continually shifting forward and backward and from side to side. We cannot tell what the caster-angle really is in a balloon-tired wheel or even in an ordinary pneumatic-tired wheel. Certainly, the point of contact with the ground, as determined by projecting the pivot, is far inside the area of the tire that touches the ground. Not only that, but the area on which the tire makes contact with the ground is constantly shifting. If we come to a bump, the area of contact momentarily moves forward. It must move forward considerably, because the bump comes up on the front side of the tire; it moves back again when it leaves the bump.

The most surprising thing that I have found is the fact that apparently a certain car shimmied worse on the smoothest possible road. Last fall I drove a car that was reputed not to shimmy. I drove it on the straightaway at the proving grounds, which is an unusually smooth piece of concrete, much smoother as to general surface than the best concrete roads as they normally are constructed. At 45 m.p.h., the car developed a violent shimmy that I was not willing to drive through.

In marine work and in airplane work, it is desirable at times to balance the effect of the rudder; in aviation, not only of the rudder, but of the elevators. It has been found by experience that practically perfect balance is to be obtained by having approximately one-third of the area in front of and two-thirds behind the pivot. If more than one-third is placed before the pivot, a violent action is produced that is almost identical with that of the shimmying of the car. If anyone has ever tried to feather an oar edgewise through the water, he has had exactly the same effect, a violent zigzag motion of the car.

It seems to me that ordinary shimmying is produced merely by the tire's taking a zigzag course on the rim, as you might say. One reason that this explanation appears probable is that shimmying does not seem noticeably to increase tire wear, which it certainly would do, if the tire were not rising from and falling to the surface of the road without extra friction.

Mr. Burkhardt brought out points very clearly as to the result of increased spring action in a tire that, because of the nature of the case, cannot be damped readily. The possible success of the balloon tire is due entirely to the lack of friction in the side-walls. Friction in the side-walls that would reduce damping would produce heat and would promptly break-down the fabric of the tire.

A balloon tire has the same effect on the rear wheels as on the front. It produces very violent rear-axle chatter on some cars, unless unusual means are taken for damping it out. I saw one car, with stiff rear springs and stiff shock-absorbers, that let the tires do all the work on a rough road, reduce the driving speed to 10 m.p.h. over a road that was easily traversed at 25 m.p.h. on hard tires. The bouncing produced by undamped balloon tires made it uncomfortable to drive the car at a reasonable speed. I am wondering how we should feel if we tried to use skates having case-hardened rubber blades. We should find it very difficult; and I think we should get results similar to those with balloon tires.

I realize that the long-felt want has not been met nor has a cure been found in anything that I have said; but I think that the only way in which we can get to the truth is by recognizing where the trouble starts. That point, I am sure, is in the natural instability of the tire itself. If any instability in the mechanism of the car can synchronize with what the tire is trying to do because of its undamped oscillations, the result will be shimmying. This accounts for the fact, which Mr. Strickland has noted, that occasionally a steering-gear that is very bad in regard to linkage may be good in regard to shimmying. It may have characteristics that, in connection with the springs, oppose the tendency of the tire to set-up oscillations and result in damping them out.

CHAIRMAN ALDEN:—When the tire makers brought out pneumatic tires, they probably made the automobile possible. The tires that they have brought out later look as if they might wreck the automobile entirely. On the other hand, the public intends to have balloon tires and engineers will have to solve the problem.

QUESTION:—It has been stated that adding weight to the rim decreased shimmying. Was the weight balanced or was it added to overcome an existing unbalanced condition?

W. R. STRICKLAND:—A series of balanced weights was attached to the rim to put sufficient energy into the revolving rim to oppose its being moved rapidly out of the line of revolution, as it has to be moved in shimmying; but the amount of weight added was so great that it was only a test, not a possibility.

Mr. Crane backs his contention by the statement that shimmying has not increased tire wear. Contrary to this, we found, as others have, that tire wear increases with shimmying. It appears in spots on the outer face of the tire, these spots occurring, generally, four to the tire.

COMBINED "TRAMPING" AND "SHIMMYING"

R. S. BEGG[21]:—In our experimental work with this phenomenon, we were not confronted with low-speed shimmying but with a combination of so-called "tramping" and shimmying that began at about 52 m.p.h., depending on conditions. In all cases, so far as we could determine, the tramping always preceded wheel wabbling. The tramping action was very severe and resulted in a swinging motion of the whole front of the car with a very considerable deflection first of one tire, then of the other.

We did considerable work on the inaccuracy of steering, on wheel balance, and with different rims, tires and the like, and found that minor changes could be made that would raise the shimmying speed to about 58 or 62 m.p.h. but would not completely eliminate the shimmying.

Our experience with wheel balance was that wheels, as received from the wheel makers, were satisfactory and

[20] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

[21] M.S.A.E.—Chief engineer, Jordan Motor Car Co., Inc., Cleveland.

ran as well as accurately balanced ones. A severe out-of-balance condition, however, such as is produced by hanging weights on the wheel rim, would aggravate the shimmying and cause it to begin at a lower speed. Rims $4\frac{1}{2}$ in. wide ran as well as rims 5 or $5\frac{1}{2}$ in. in width. A slight inaccuracy in steering had some, although not a serious, effect on the car.

By running tests with weak steering-knuckle arms and a big bow in the tie-rod, we were able materially to lower the speed at which shimmying would occur. This led to the conclusion that rigid steering-arms and tie-rods are desirable. We found that the caster-angle should be held within close limits.

Early in our work, we found that blocking-up the front spring, when the tires had more than 20 lb. per sq. in. pressure, eliminated tramping and wheel wabbling up to the limit of the car speed. This led to tests with very stiff front-springs and various shock-absorbing devices. The absorbers helped the wheel wabbling but resulted in hard riding. We also found that tramping and wheel wabbling could be prevented by increasing the tire pressure from 25 lb. to 32 lb. We then returned to our original spring specification, continuing the tests until we discovered one day that the periodicities of the front tire and of the spring were the same.

In view of our experience with blocking-up the front springs and increasing the tire pressure, we concluded that we could not lay all the blame on the tires, but that perhaps the trouble was with a combination of the springs and the tires. Accordingly, we tried weaker front springs and found one that apparently gave just the right combination with the tire periodicity. So far, and in connection with other changes that we have made during repeated tests over all types of road, we have been unable to get either a tramping or a shimmying action with this combination.

We assume that the difference in periodicity tends to damp-out the tendency for road inequalities to set-up a periodicity in the spring and the tire that would build-up to the maximum, create a tramping action and thus induce shimmying. We believe, in our case, that the tramping action, which produced a severe deflection first of one tire, then of the other, increased the drag on one wheel, because of the increased rolling resistance plus an increase in the lever-arm, and relieved it at the same time on the other wheel, producing an adverse steering action and inducing the wheel shimmying. We make no claim that this is an effective cure for all cars; but, in our own case, the least we can say is that it has made a marked improvement. At first the rate of vibration was from 187 to 190 per min.; the weaker spring has a rate of 140 vibrations per min.

Rubber Shock-Insulators

P. H. Geyser[22]:—So far as shimmying is concerned, we have eliminated all of ours by inclining the steering-knuckle pin. We made no changes in the springs, steering hook-up or anything else.

I think that we really pioneered some of the balloon-tire activities that presented themselves about 3 years ago. We have gone through all the hard knocks that might be expected and have found that for our particular service a strictly balloon tire is not the thing to use. We use a semi-balloon tire and have found it to be far superior to anything else that we have ever tried. Further, we use rubber shock-insulators. I think that they have been a great help, so far as shimmying is concerned.

Mr. Strickland:—Low-speed shimmying is likely to occur with rubber shackles and can easily be cured by giving more caster-angle. If that were all, the problem would be easy, but whatever is done to cure low-speed shimmying seems to make high-speed shimmying worse; or, if the high-speed kind is cured, you run into the low.

Chairman Alden:—A popular impression exists that Yellow cabs are driven only at low speed, but I think that impression is largely erroneous.

Question:—If the two front wheels and the front axle were made into one solid piece there would be no steering-knuckle. Would the spring and the backlash still allow shimmying on either a smooth or a rough road?

O. M. Burkhardt:—We must have forces. They are there. If we have impacts and looseness and they synchronize, we have shimmying whether the two wheels are linked or not. If, on the other hand, we stop the shimmying on only one wheel, as in the case of the Goodyear device, we also stop the shimmying of the other wheel. In other words, it is a case of having masses, forces, slackness and periodicity. If we provide friction or resistance and break up the periodicity, we shall not have shimmying.

Question:—Does not the balloon tire reduce the desirability of low unsprung weight? Would not greater unsprung weight be beneficial?

Mr. Burkhardt:—Decidedly not. I could never reconcile myself to the idea that greater unsprung weight would be beneficial in an automobile. Once in a while, the argument is raised that the greater the unsprung weight and the closer the axle hugs the ground the better, but the forces between the tire and the road are so much greater that unsprung weight is usually considered a detriment; the lighter we can make it, the better off we shall be.

Question:—Does tramping ever occur in the rear wheels?

Mr. Burkhardt:—It is likely to occur to some extent, but is seldom noticed except by persons riding away back and they usually have to watch some other part of the car and not the axle to notice it. If tramping is present, it is not noticed.

Chairman Alden:—A suggestion is offered for the solution of this matter: "Drive your cars from the other end." That might be done. We steered them that way years ago.

Question:—Considering modern tire-service facilities, does any serious objection exist to treating the front end of the car differently from the rear end and using small high-pressure tires in front and full balloons at the rear?

Mr. Strickland:—I think that would not be advantageous. It would be better to carry higher pressure in the front than in the rear, but I believe it would not be very practical and the car would be very bumpy in front. It would be better to use a moderate-size tire with medium flexibility and to vary the pressure to suit the conditions of driving. Any owner can get good results with medium balloon tires by varying the pressure. If they are driving about town, they can take advantage of the low pressure; if they go out into the country, and if they are going to exceed the speed limit, they should remember to raise the pressure. I would say that shimmying which begins at about 35 or 40 m.p.h. is of the high-speed type; and below that, it is of the low-speed type.

A Member:—Our experience in investigations covering a large number of different makes of car, as well as different sizes of tire, is somewhat different from

[22] M.S.A.E.—Vice-president and general manager, Yellow Cab Mfg. Co., Chicago.

Mr. Strickland's. For instance, we have yet to find a car that would shimmy at any speed, at any inflation-pressure and with any size of tire, if the front springs were blocked. Perhaps his difficulty resulted from not clamping the frame rigidly to the axle by a stirrup or other means.

The point is that it is not sufficient merely to place a block between the springs and the frame. A certain amount of motion is present that is sufficient to initiate the vibrations that start shimmying. Likewise, under the same general conditions, we have yet to find a car in which shimmying cannot be eliminated by the hydraulic steering-gear that Mr. Hale has described[23]. That gear, of course, was simply an expedient to steer the car temporarily without the mechanical connection, the drag-link. Under those two conditions, shimmying is absent.

Mr. Burkhardt has very tersely summarized the fundamentals involved in shimmying. It is largely caused, perhaps a better word would be aggravated, by numerous vibrations that harmonize at different periods, producing resonance; and as soon as we have resonance in some cars, we have "an excellent time."

In speaking of shimmying, I am referring solely to the lateral, or perhaps the transverse, motion of the front wheels. In our experience, tramping and vertical acceleration or vertical rotation, we might say, around the center of gravity of the car, is largely a factor of spring-suspension, rather than of spring plus tire-cushioning properties.

Causes of and Remedies for "Tramping"

H. A. Huebotter[24] and G. A. Young[25]:—High-speed car-shimmying, usually designated as "tramping," seems to be an indirect result of the heavy front axle and the low-pressure tire. The term aptly describes the violent seesawing of the front axle, which is characteristic of shimmying. The phenomenon is noticeable from the car as a severe horizontal shaking of the radiator. An observer on the road is impressed with the rapid transverse vibrations of the front wheels. The whole behavior of the car indicates the presence of an alternating force of high frequency. The purpose of this written discussion is to point out the origin of a force that will produce such an effect and to present methods of damping it out.

It is apparent that the entire so-called unsprung weight of the car is suspended between highly elastic supports: the tires below and the springs above. In this position the front axle is free to vibrate vertically with a wide range of amplitude, damped only by frictional resistance. If the axle receives enough impetus in phase with its oscillations to overcome friction, the vibrations will continue indefinitely. The problem then is to: (*a*) determine the conditions of axle vibration; (*b*) analyze the effect of this vibration upon the car; and (*c*) show that a force may exist to amplify the vibration.

The experimental part of the research herewith reported comprised the study of the free-vibration periods of the tire and of the spring. A 6 x 21-in. tire, mounted on a wheel and spindle, as illustrated in Fig. 9, was bounced under various loads and air-pressures. Movement of the tire was maintained by hand with the lever and fulcrum shown at the right. The number of bounces was registered by a counter actuated by the lever, and the time was taken with a stop-watch. The ratio of the two readings gave the vibration-frequency. No difficulty was experienced in keeping the impulses of the lever in phase with the rebound of the tire, but the amplitude of the movement seemed to have some effect upon the frequency.

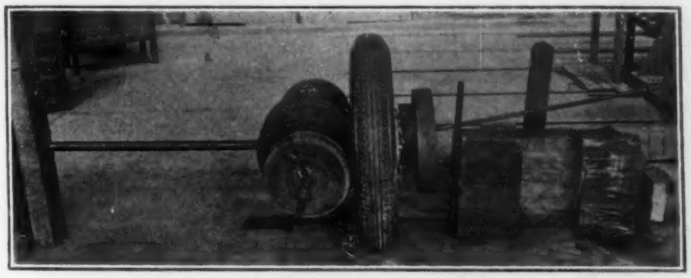

Fig. 9—Apparatus for Studying Free-Vibration Periods

A 6 x 21-In. Tire Was Mounted on a Wheel and Spindle and Was Bounced under Various Loads and Air-Pressures. Movement of the Tire Was Maintained by Hand with the Lever and Fulcrum Shown at the Right. The Number of Bounces Was Registered by a Counter Actuated by the Lever, and the Time Was Taken by a Stop-Watch. The Ratio of the Two Readings Gave the Vibration-Frequency. No Difficulty Was Experienced in Keeping the Impulses of the Lever in Phase with the Rebound of the Tire, but the Amplitude of the Movement Seemed To Have Some Effect upon the Frequency

The balloon tire was tested at air-pressures of 15, 25 and 35 lb. per sq. in. and at loads ranging from 250 to 1000 lb. A 4 x 33-in. tire was then substituted and tested at 45, 55 and 65-lb. per sq. in. air-pressure over a load ranging from 500 to 1000 lb. The results of these tests are presented in the six upper curves of Fig. 10. The effect of tire section in the interval between 35 and 45 lb. is negligible and the frequency seems to be chiefly a function of the tire load and of the air-pressure. A similar test was then conducted upon a front spring of a car susceptible to shimmying. The vibration-frequency at different loads, which is given by the lowest curve of Fig. 10, follows the simple law of a spring with a scale of 520 lb. per in.

The curves in Fig. 10 illustrate the characteristics of

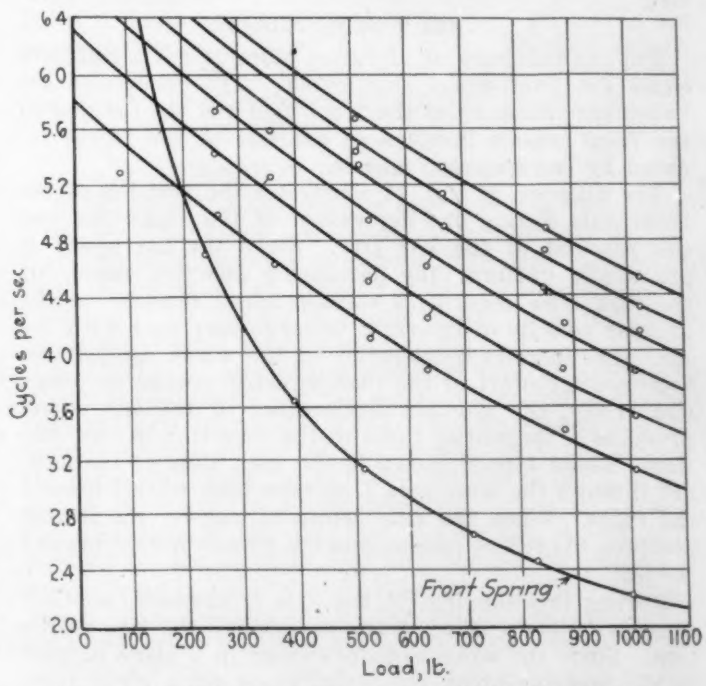

Fig. 10—Results of Tests for Free-Vibration Periods

Test Results Are Shown by the Six Upper Curves, and the Vibration Frequency at Different Loads Is Shown by the Lowest Curve on the Chart, for Tests Made Upon a Front Spring of a Car Susceptible to Shimmying

[23] See The Journal, December, 1924, p. 505.

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[25] M.S.A.E.—Head of the school of mechanical engineering, director of mechanical engineering laboratories, Purdue University, Lafayette, Ind.

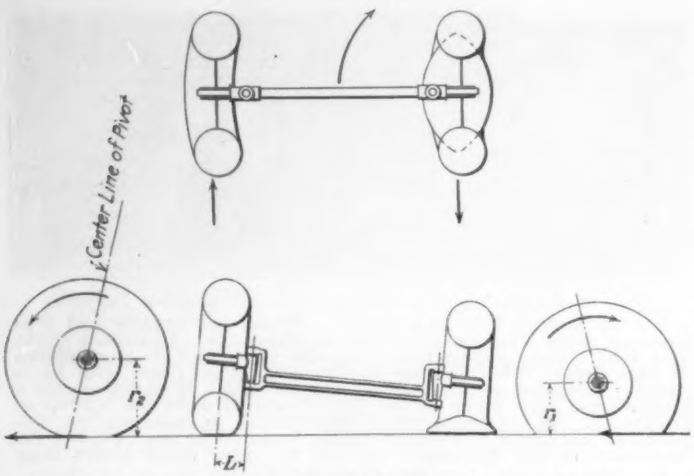

FIG. 11—FORCES ON THE FRONT WHEELS DUE TO "TRAMPING" ACTION

The Position of the Front Axle during the Depression of the Right Tire and the Rebound of the Left Tire Is Illustrated. The Forces Shown in the Plan View of the Axle Act through the Lever Arm *L* To Turn Both Wheels Toward the Right. When the Axle Begins To Recover Its Normal Position, the Forces Reverse and the Wheels Swerve Toward the Left

the spring and of the tire, individually. It may be shown, both mathematically and experimentally, that the frequency of a mass suspended between two springs is equal to the square root of the sum of the squares of its frequency with each spring alone. Although the tire curves do not conform to the simple harmonic law of a steel spring, the use of the series spring relation will suffice for our purpose. The front unsprung weight on the car investigated was approximately 210 lb. per wheel and the axle should, therefore, vibrate at the rate of 7.1 cycles per sec. with 15-lb.; 7.5 cycles per sec. with 25-lb.; and 7.8 cycles per sec. with 35-lb. per sq. in. air-pressure. If the spring were 50 per cent stiffer, the frequencies would be 8.0, 8.3 and 8.6 cycles per sec. respectively. It is evident, therefore, that the axle will vibrate regardless of the relative frequencies of the spring and of the tire.

OTHER FORCES INDUCED

But the existence of vibration alone is not a sufficient cause for front-wheel shimmying. The connection between the tramping of the front axle and the turning of the front wheels involves an analysis of the forces induced by the bouncing wheels.

The diagram in Fig. 11 illustrates the position of the front axle during the depression of the right tire and the rebound of the left tire. Since the car speed is practically uniform, the decreasing effective radius of the right tire requires a corresponding increase in the angular velocity of the right wheel to keep pace with the car. The angular acceleration of the wheel necessitates a tangential effort at the road directed toward the rear. Conversely, the angular deceleration of the left wheel produces a tangential force in the direction of car motion. These forces, shown in the plan view of the axle, act through the lever arm L to turn both wheels toward the right. When the axle begins to recover its normal position, the forces reverse and the wheels swerve toward the left.

During this turning, if the axle is castered, another force is built-up which tends to amplify the tire vibration. Since the wheel spindle swings in a plane normal to the steering-pivot, the right wheel on a right turn will fall below its straightaway position with respect to the axle bed. To do this, either the tire must depress, or the whole front end of the car on the right side must rise. The inertia of the upper chassis renders the former action the greater. The effect on the left tire is the reverse, and its radius therefore increases. Hence, the amplitude of tire deflection induced by the original cause is aggravated by the castered pivot and a self-generating system of forces tends to bounce the axle and thereby to turn the car.

The remedy for front-wheel shimmying naturally consists in removing any one of the causes. Axle vibration may be damped by friction between the spring leaves, within the steel itself, in the walls of the tire, or in an external element such as a shock-absorber. The magnitude of the tangential force between the tire and the road, purely an inertia reaction, depends upon the change in the tire radius, the wheel speed and the moment of inertia of the wheel. High air-pressure, low car-speed, and light-weight wheels all reduce this force. Since the turning-moment at the steering-pivots is the product of the tangential force at the road multiplied by its lever-arm, the latter should be reduced to the minimum. The turning-effort must overcome the friction on the steering-system before it can begin to swing the wheels. For this reason, a brake on the steering linkage will inhibit shimmying, although it is not conducive to easy driving. A more satisfactory form of check is a dash-pot, to prevent rapid movements without affecting normal steering. At high car-speeds, the gyrostatic action of the wheels tends to hold them in the straightforward position. At high vibration-frequencies, the inertia of the wheels causes a lag in their response to the turning-effort.

RESULTS OF USING STIFFER FRONT-SPRINGS

Some of these remedies are inherent in automobile design; some are barred by other considerations. But a cure that has been applied with excellent results is the substitution of stiffer front-springs. All shimmying was eliminated without detracting from the riding-qualities of the car. The new springs had fewer and thicker leaves, which, perhaps, introduced greater interfacial friction between the leaves and greater molecular friction within the metal.

The principal advantage of stiff springs, however, seems to lie in the smaller amplitude and the higher vibration-rate of the axle. The former reduces the periodic change in effective tire-radius; the latter brings the frequency of the stress reversal nearer to the critical speed at which the gyrostatic action and the inertia of the wheels prevent their following the fluctuations of the turning-force. It is obvious that the drag-link must be designed to allow oscillation of the axle throughout its full amplitude without affecting the direction of the front wheels. The car in question was almost perfect in this respect.

The authors wish to acknowledge their indebtedness to F. F. Chandler for his cooperation in connection with these tests.

MATHEMATICAL ANALYSIS

Some conception of the forces produced at the wheels by the tramping axle can be gained from the following analysis. The instantaneous angular-velocity of the wheels is $\omega = 17.6\, v/r$ radians per sec., where v is the car speed, in miles per hour, and r is the effective wheel-radius, in inches. The mean angular acceleration of the wheel from one extreme position to the other is $\alpha = 2\, (\omega_1 - \omega_2)\, f$ radians per sec. where f is the number of vibration-cycles per second. Hence,

$$\alpha = 35.2\, vf\, (1/r_1 - 1/r_2)$$

If the mass polar moment of inertia J of the front wheel

is $g \times$ lb-ft.^{2}, the mean tangential effort T required to produce this acceleration is $T = J\ (\alpha / r)$. Hence

$$T = 422.4\ (vJf/r)\ (1/r_1 - 1/r_2)\ \text{lb.}$$

applied at the normal radius, r in. At a car-speed of 40 m.p.h., with a vibration-frequency of 7.5 cycles per sec., a moment of inertia of 1.85 and radii of $r = 15.5$, $r_1 = 15.0$ and $r_2 = 16.0$ in., and $T = 64$ lb. per wheel. If the lever-arm L is 0.5 in., the resulting turning-moment about the pivots is 64 in-lb., which is ample to swing the rolling wheels on a hard road surface.

The elements necessary to the inception and the perpetuation of front-wheel shimmying are, therefore, as follows:

(1) Low free-vibration periods in the front springs and tires under a load equal to the unsprung weight per front wheel
(2) A road shock to cause unequal deflection in the two front tires
(3) Sufficient deflection in the tires to affect the instantaneous angular-velocity appreciably
(4) High enough road-speed to set-up large kinetic forces by the angular acceleration of the wheels
(5) Fore-and-aft rake in the steering-pivots
(6) Little friction in the steering mechanism and the front springs

CHAIRMAN ALDEN:—Your experiment showed that increasing the stiffness of the front spring decreased the shimmying?

MR. HUEBOTTER:—It eliminated it entirely. At no speed and at no tire-pressure could we get shimmying.

CHAIRMAN ALDEN:—Mr. Begg did just the reverse; he lightened the front springs and got the same result.

MR. HUEBOTTER:—The matter simply returns to the combination of the frequencies of the spring and of the tire. If they have the right magnitude, we can get shimmying because we have large enough kinetic reactions to produce an effective turning-moment about the steering-pivots.

CHAIRMAN ALDEN:—Mr. Begg told me recently that he demonstrated this point on his car beyond any question of doubt. Making the front springs lighter damped out shimmying almost entirely. I suspect it must be from the same cause operating in both directions.

MR. STRICKLAND:—I said in my paper that a great many cases of mild shimmying could be and had been cured in one way or another but, to get to the bottom, the worst cases of shimmying should be used. All the conditions of heavy weight, low air-pressure, large tires, flexible side-walls and all the extreme conditions should be used in making the test. When that is done, the subject becomes much more difficult.

MR. HUEBOTTER:—In response to that, I might say that I rode on the front fender of a car that shimmied and I do not wish a more thrilling ride.

OTHER MEANS OF PREVENTING SHIMMY

W. G. WALL[36]:—In his paper, Mr. Chandler said something to the effect that, as so many other things can cause bad steering, it is hardly fair to put it up to the steering-gear to prevent shimmying. In fact, it does look as if to do so was to begin at the wrong end. The shimmying should be stopped at its source. That also seems to be a rather difficult thing to do.

The next proposition is to stop it when it is in the initial stages, in other words, to catch it when it is young. We know that the vertical movement is practically the beginning of the shimmying that transforms itself into the horizontal movement. So far as the vertical movement is concerned, we get along very well with it; in fact, the rear wheels have practically the same vertical movement, but it is the horizontal movement that troubles us. The initial force is rather small, although, if allowed to go on, it assumes large proportions.

I have noticed as no doubt many others have noticed in driving a car on a motor-driven roller-tester that, when driven fast, a certain amount of shimmying of the front wheels can be obtained, especially if the roller is a little rough. If you put your hand on the steering-arm at the beginning of the shimmying, you can prevent most of this; whereas, if you allow it to start, it takes a great amount of power to stop it. Mr. Hale has worked along this line in his suggestion of the dash-pot. It looks as if something of that kind is, possibly, one of the feasible and simple ways of preventing shimmying.

On account of the small amount of damping effect that is necessary at the beginning of the shimmying, I wonder whether it would not be possible, as an interesting experiment at least, to put two vanes on top of the steering-knuckle, attached to the king-pin, that would, in turn, be attached to the knuckle, and over it to put a cap with a couple of stationary vanes, use oil and use a small bypass. Would a damping device of this kind, which could be made very small, say from 2 to $2\frac{1}{2}$ in. in diameter, be sufficient to damp out these forces so that they would never get started?

CHAIRMAN ALDEN:—This whole meeting is a source of much pleasure to me as an axle-builder. When the shimmying condition first arose, we were blamed as being the cause of the whole thing. Now it develops that we are not to blame. It is up to you gentlemen to settle it. I think that, within a few weeks, we shall have on the road some front axles with very nearly center-point steering and vertical king-pins, and built so that things can be shifted about a little. I had hoped to have these axles running before now so that we should have a little light to throw on the subject; but as soon as we can get some information about these axles, whether center-point steering and a vertical pivot almost in the center line of the wheel produce satisfactory results, we will turn it over to the Society.

CALIBRATION OF TEST APPARATUS

J. H. HUNT[37]:—Concerning one point in connection with Mr. Chandler's instrument, I do not wish my remarks to be interpreted as unfavorable to the instrument or to the effort he has made; I think it a very commendable work. It is only a minor matter with regard to calibration that I have in mind.

Mr. Chandler uses oil transmission from the piston to the recording device. It has come to my attention lately that another instrument using oil transmission had an appreciable amount of lag. If he happens to get exactly the same amount of lag in both lines and is not attempting to tie-up his record to any other point in time in the operation of the car, the records are correct with relation to one another; but if a lag exists, and he is undertaking to get a record of the very rapidly reversing forces that may occur in some cases, the calibration obtained under static conditions will not obtain under rapidly accelerating forces. The point is that, when the calibration is made, an attempt should be made to get measures of definite rapidly applied forces as compared with those of steadily applied forces.

This seems to be so beautiful an instrument for obtain-

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[37] M.S.A.E.—Head of the electrical division, General Motors Research Corporation, Dayton, Ohio.

ing information on a subject on which considerable light is needed that it seems to me very desirable to try to make this first set of tests as complete as possible and to avoid all elements of question.

F. F. CHANDLER:—I have already realized what Mr. Hunt has said with reference to calibration, but I still claim that some benefit can be derived from the use of the instruments. It was very difficult to determine just how the instruments should be built. It was only after a long investigation of the various methods of producing the reactions that we finally got back to the hydrostatic method. Mr. Hunt is entirely correct. It is impossible to assume that a different set of conditions would not throw the whole instrument out, because it will.

SIMPLE AND COMPOUND SPRING-SYSTEMS

GEORGE L. SMITH[28]:—As the ground is the ultimate point of support, the irregularities of which the engineer attempts to eliminate by the use of a compound spring-system composed of two simple ones, namely, the body springs and the wheel springs or tires, it is theoretically sound to assume that these irregularities could be eliminated by the use of either one of the two simple spring-systems having the characteristics of the compound system. Were it practicable to construct and use tires to meet these requirements, body springs would be eliminated and all weights would then be carried on the springs. Conversely, if tires having no resilient qualities were used, then body springs of great resiliency would be required and axle and wheel weights would be entirely unsprung weights.

Conditions at any point between these two extremes must be governed by the relative characteristics of the body springs and tires. An increase in the capacity of the tires to absorb shocks must mean the equivalent of a reduction of unsprung weight, since this change is in the direction of its entire elimination. This leads to the question: Has the increase in tire resiliency been so great as to reduce the unsprung weight beyond the desired point? Could this unsprung weight be reduced to zero, this question would not come up; but, since it is practically impossible, the unsprung weight must have a certain most desirable value that will produce a vibration period as nearly as possible incommensurate with that of the sprung weight. The axles constitute masses in suspension between two springs, and the vibratory action of these masses may tend either to damp or to accentuate the movement of the car body.

GLIMPSES OF BALLOON-TIRE PROGRESS

BY B. J. LEMON[29]

ABSTRACT

THE balloon tire has run the gauntlet of skepticism and credulity, and has received scientific and popular approval from engineers and car-owners. The reasons for its acceptance are satisfactory appearance, practicability and transportation comfort. Tire and rim sizes, masquerading for years under wrong dimensional markings, have caused immeasurable inconvenience. This condition resulted from poor standards or entire lack of standards supervision. A committee with backbone is needed to fix and to maintain standards.

Rapid balloon-tire tread-wear depends on tread profile, pressure and movement. Increased inflation-pressure and a scientifically designed tread will reduce the rapidity of this wear. Tread-contact areas and pressures are pictured to explain the advantages of a properly designed tread, and to demonstrate that the casing carries an appreciable part of the tire load. Tread configuration should assure traction, flexibility, easy steering and good wear, and should be not too rugged. Tread surface should be largely non-skid for best all-year and all-highway service. The public is confused by diverse balloon-tire inflation-pressure tables offered by tire and vehicle makers. One standard table can and should be adopted for all balloon tires.

Increasing the number of plies in a balloon tire increases the ease of entry of a puncturing object into the tread, but decreases the probability of complete penetration and actual deflation from puncture. Gradual loss of air from tires is due chiefly to diffusion through the tube rubber. The rate depends on daily mileage, road conditions, tube quality and thickness. Average diffusion amounts to from 1 to 5 lb. per week.

Volume of noise in closed cars is no greater with balloon tires than with high-pressure tires, as indicated by audiometer measurements. Different cars show important differences in noise volume, due principally to differences in engines. Balloon tires are not a fundamental cause of shimmying. Improper balance between front-end units appears to offer the chief cause. There is no common remedy. More original and thorough research by experts in their particular fields is urged so that America will lead in the refinement as well as in the production of tires and automobiles.
—[Printed in the February, 1925, issue of THE JOURNAL.]

THE DISCUSSION

W. R. GRISWOLD[30]:—Mr. Lemon's paper has touched lightly on the uneven wear of balloon tires on the front wheels in mentioning that the cause of tire wear is excessive toe-in and pitch of the wheel planes. This point deserves more than casual reference because uneven and excessive wear of the front tires seems, to the car-owner, to be about as inexcusable as is failure of the steering-gear.

Four-wheel brakes followed closely the introduction of balloon tires, and many believe that the greater inclination of the king-pin, required in center-point steering, was to blame for excessive tire wear. This belief probably was exploited by tire manufacturers to detract blame from their tread design. Nevertheless, to whatever extent wear is related to tread design, the same laws of surface wear apply to tires, if the slippage of the tread on the surface of the road is augmented by other factors.

For the most satisfactory steering from a given layout, a definite relation exists between the toe-in of the front wheels and the inclination of the wheel planes. Some pitch is desirable, to give stability in steering, but the amount of pitch varies in a sort of haphazard arbitrary manner. The correspondingly best toe-in usually is determined experimentally for any arbitrary pitch of the wheel plane and is related to the pitch by reason of the mechanics of rolling bodies. When the axis of the wheel is horizontal and is rolling on a level surface, the

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[29] M.S.A.E.—Research department, tire division, United States Rubber Co., Detroit.

[30] M.S.A.E.—Engineer in charge of analysis of design, Packard Motor Car Co., Detroit.

rolling action corresponds to that of a cylinder rolling on a flat plane. When the axis of the wheel is inclined to the horizontal, the free path would be the same as the action of a rolling cone having its base formed by the wheel plane, and having its apex located at the intersection of the wheel axis and the plane on which the wheel is rolling. Hence, the natural path of the wheel is an arc; and, if both front wheels were free, they would tend to separate at the front. Since the wheel spindles are coupled together by the tie-rod, the path of the wheels cannot diverge, but the diverging forces still act and, if no toe-in were provided, steering would be affected. Obviously, the factor of movement or slippage of the tread on the surface of the road is increased by the departure of the constrained path of the wheels from the natural free path and, therefore, the wear of the tire is increased.

Causes of Tire Wear

At the Packard Company, we have thoroughly investigated this problem; and actual tests have shown that the pitch of the wheel, rather than the inclination of the king-pin, is largely responsible for the part that the mechanics of steering plays in tire wear. In one test, we decreased the pitch of the wheel but maintained center-point steering by still farther increasing the inclination of the king-pin. In these tests, the tire wear was considerably reduced and the unevenness of the wear was largely overcome.

In connection with the standardization of tires, too much emphasis cannot be placed upon the need of uniform rolling circumferences for all makes of tire denominated by a particular standard size. Many unjust complaints have been made to car manufacturers because of the practice of tire companies of increasing the sections of tires to gain sales advantage. Anyone who has been forced by circumstances to run a large tire opposite a smaller one on the rear axle appreciates very well the need of uniformity. Steering is affected, and the driver's control of the car often becomes trying, in the effort to maintain a straight course.

A car manufacturer, in selecting the outside diameter of the tire for a new car, is governed chiefly by road clearance. Once this diameter has been selected, and the design of fenders, the axle ratio, the speedometer ratio and the desired performance of the car have all been established, it becomes an essential part of the manufacturer's integrity and fair dealing to his customers to furnish tire and wheel equipment that is as nearly standard as it is possible to obtain. From the standpoint of the design and the performance of the car, the rolling circumference is of primary importance; and tires ought to be standardized on this basis. Then, if, by the judicious grading of tire sections and designs, a single standard wheel-diameter could be adopted, the ideal of standardization will have been accomplished.

Elimination of Noise

From the car manufacturer's viewpoint, noise is one of the most troublesome factors with which he has to contend. All the present methods of determining noise by audiometers are based entirely upon the relative energy of sound waves and not on the psychological value of the sound. Practically, the only way to ensure the absence of psychologically bad noises is to obtain perfect silence. Automotive engineers, when selecting tires and treads, are very much concerned with the effect of the tires' exciting small noises in other parts of the car. One of the most distressing noises in an automobile is rear-axle gear noise. Although this noise is very small, when its volume is compared with that of the general noisiness, it usually has a penetrating and irritating pitch. Nevertheless, an audiometer would show this noise as being of scarcely any importance. To draw a reasonable inference, it must be said that audiometer measurements do not prove contentions regarding balloon tires and noise; and the car manufacturer gives preference to treads that do not excite forces which cause noise in the mechanical functions.

The remarks on shimmying seem to have been made in an effort to absolve the tires from all blame for the motion of the front wheels that this familiar word describes. As stated in the paper, the first impulse was to attribute shimmying to the tire; and this diagnosis is not such poor logic as we might be led to believe, because the springiness of the tires is as much a fundamental factor in shimmying as is the steering-layout or the elasticity of the front axle and the steering-system. To hark back to the very fundamentals, we must consider all the bodies and springs that compose this system.

Synchronized Vibratory Motion

When we get a condition, in any kind of mechanism, in which periodic changes take place in the magnitude or in the direction of the forces that act on elastically connected bodies in such a way that the elastic and inertia forces of the bodies are timed with external forces, we obtain a state of synchronized vibratory motion; and the amplitude grows until equilibrium has been established with the damping forces. Getting back to the specific motion of shimmying, we can enumerate, as the elements entering into the motion: (*a*) the external forces, (*b*) the rotation of the front wheels, (*c*) the mass and mass distribution of the bodies and (*d*) the elastic properties.

Considering first the external forces, we have road shocks and inertia forces produced by changes in the motion of the car as a whole; also, tractive road forces on the tires. Because of their rotation, the wheels possess all the dynamic characteristics of flywheels and, therefore, if rotation of the wheels also takes place about another axis such as that of the king-pin, some large acceleration forces will be produced. Mass and mass distribution determine the inertia characteristics of a body; hence, the dynamic forces arising from the motion of the body. For illustration, the magnitude of the flywheel effect of the front wheels is determined by the mass moment of inertia; and the balance of the wheel depends on the location of the center of gravity of the wheel with respect to the axis of rotation. Elastic properties have to do with the elasticity and the distribution of elasticity in the system, for instance, the elasticity of the springs, tires and the various mechanical members of the car, such as tie-rods, drag-links, and the like, all of which are springs to a greater or lesser degree.

A complete conception of front-wheel shimmying involves consideration of a large number of factors, and any attempt to describe the motion without the aid of mathematics is difficult; but, in an ideal condition in which the car is running along a straight path on a smooth flat level surface, let us consider that traction is constant, that tractive resistance is constant, and that the wheels have perfect alignment. Let us assume that the tire and wheel assemblies are perfectly balanced, both statically and dynamically. For this operating con-

dition of the car, all forces will be in equilibrium and no shimmying will take place. The tires in rolling contact with the surface will be compressed by a constant amount in going into road contact; hence, the vertical and tangential reaction between the tires and the road will be constant.

This condition of operation is really the mathematical condition under which no shimmying can take place, and can be taken as the starting-point from which practical conditions diverge. By adding various factors, one at a time, we can study their effect on the front axle and the steering-system or, more generally, on the action of the car on the road.

Degrees of Unbalance of Tires

First, we will study the effect of unbalance of the tires, the degree of unbalance, let us add, that has actually been obtained in practice. In some tests that we conducted at the Packard factory, we fitted up a Crawford flywheel-balancing machine to determine the unbalance of the tires. In seven series of tests, in which the carcass was moved 90 deg. with respect to the tube four times in each test and the unbalance obtained, we found the centrifugal forces produced by unbalance to range from 3.1 to 107.6 lb. for a speed of 60 m.p.h. By simply shifting the casing 180 deg., the unbalance was changed from 28 to 107 lb. in one test.

If we have unbalance in only one tire, the centrifugal force owing to this unbalance acts as an arm about the king-pin, producing a considerable turning-moment and, with each revolution of the wheel, a reversal of this turning-moment takes place. The turning-moment is resisted by the members of the steering-system; hence, we get a complete oscillation of stress and a deflection in the steering-system with each revolution of the wheel. If the number of revolutions of the wheel should correspond to the vibration-frequency of the steering-system, the deflection will grow until the spindle wabbles back and forth over a considerable angle. But the first wabble brings other forces into action; for instance, when the front wheels are deflected sidewise, the path of the car is changed; hence, the forces acting through the center of gravity of the car tend to list it from one side to the other. The sidewise listing of the car can take place only because the elasticity of the car springs and of the tire allows it; hence, periodic elastic forces are excited in the springs and in the tires and, when the condition of synchronism occurs, a good-sized wheel wabble or shimmying will result.

Generation of Accelerating Forces

The wheels also generate important accelerating forces. A wheel revolving at constant speed in perfect balance is in equilibrium. If the wheel, when rotating at constant speed, is at the same time rotated about the king-pin or any other axis, the periphery of the wheel is no longer traveling at constant velocity; hence, it is accelerated. Because of the inertia of the wheel, accelerating forces are created. Such an accelerating force, known as a gyroscopic couple, can also be excited by vertical motion of one wheel with respect to the other. If the wheels are wabbling, the gyroscopic couple tends to lift one wheel and to depress the other, bringing into action, of course, the elastic forces of the tires and the springs. With this complex system of periodic forces, when the forces are of sufficient magnitude and are properly timed, a considerable wheel wabble will be created.

Next, let us assume the ideal condition with which we began, and that the car rides over an obstruction with one wheel. We see that we immediately bring the elastic force of the tires, the steering-system, the gyroscopic couple and the mass of the car into action with the tangential force of the impact on the tire. If, at this particular instant, a proper time relation exists, the gyroscopic forces will prevail and will maintain the motion along with the elastic forces; hence, shimmying will again be produced.

In connection with the steering-layout, if we start out with the ideal conditions and run over an obstacle, we get a very large exciting force because of the geometry of the steering-system. In this case, the wheel is suddenly flung around the king-pin, bringing into play a very large gyroscopic force and the various elastic and inertia forces already mentioned.

In like manner, we can study the influence of king-pin inclination, wheel camber and toe-in; but these, relatively, are of small importance. Thus, we see that the elasticity of the tire is, in itself, a fundamental element in the vibratory characteristics of the front-axle system. That is the reason for so universal success in curing shimmying by increasing the tire pressure. One method of avoiding shimmying consists in removing all the exciting forces. This would mean the elimination of the effects of road shocks and of rotating unbalance.

In addition, we could tackle the problem from a mass point of view. If we could provide wheels of negligible mass, all internal inertia forces would be eliminated. Another method consists in taking the situation as it stands and in adding auxiliary apparatus to offset some of the inherent forces; that is, adding damping forces. It is not necessary, however, to go to the extreme of eliminating the various external inertia and elastic forces, but simply to reduce the effect below the inherent damping forces.

Practical Method of Procedure

To overcome shimmying with balloon tires, therefore, the most practical method of procedure is to:

(1) Obtain the best possible balance of the tires
(2) Reduce the exciting forces produced by road shocks to the minimum by providing the proper geometry of the steering-layout
(3) Keep the rotating mass-inertia of the wheels down to the minimum
(4) Provide sufficient stiffness in the mechanical layout of the steering-system
(5) Take advantage of all the damping forces possible, without sacrificing riding comfort or ease of steering, such as the utilization of inter-leaf friction of the front springs to dissipate vibrational energy

Pitch and Toe-In Effects

B. J. Lemon:—The discussion submitted by Mr. Griswold is well thought out and fundamentally sound and will bear close study throughout by vehicle and tire engineers. That part which covers the method of arriving at, and the relationship of, pitch and toe-in to tire wear is especially noteworthy. Too few reliable facts and too much unreliable hearsay have been published on this subject, as affecting car design and operation, and especially as affecting the wear of different types of tire.

If, as Mr. Griswold generalizes, it is pitch rather than

toe-in that most vitally affects balloon-tire wear, greater care should be exercised that the proper amount of pitch be given the wheels when the car is built, because of the difficulty of changing the pitch after the car has been sold. Correspondingly, less emphasis should be placed on the comparative importance of maintaining toe-in, as contrasted with pitch, by service-stations and dealers that purchase and apply wheel alignment instruments, some of which are designed to measure toe-in only.

Tire Heights and Sizes

The remarks anent standardization of tire heights and sections are very much to the point, but the accomplishment is not in sight. The vital question is: Who will hold a club over the car manufacturer and say that he must not solicit nor accept other than certain standardized tire-sizes? Who has the power and the gumption to tell the tire-maker to restrict production to such sizes and limits as already have been or will be approved? The inconvenience of which Mr. Griswold complains is indeed important, but this is far overshadowed by the waste in effort and equipment on the part of the tire industry. If the related industries will not see their way clear to attempt adequate and satisfactory supervision, has the Department of Commerce the necessary authority to stop the leak, and will this department initiate a suitable program?

Audiometer Detection of Noise

That audiometer measurements of sound volume do not segregate noises produced by a particular part of a car's mechanism is true, but is not of the greatest importance. What is more vital is, whether research is being carried on to reduce the total volume of noise in closed cars, as well as the particular noises that irritate the passenger and sap his energy. Also, will an effort be made to develop the audiometer or other instruments of like nature, so that noises in automobiles can be segregated and traced to their origin, as a further step in car refinement? To dismiss audiometer measurements of noises in automobiles as unimportant because not psychologically measurable is not a constructive method of solving the noise problem.

Tire Balancing

Mr. Griswold discusses in detail the problem of shimmying, and cites, as one method of procedure, the obtaining of the best possible balance of tires. Tire manufacturers, in general, are doing this to the best of their ability on a production basis. But what are the wheel and the rim manufacturers doing in the meantime to help alleviate unbalance? Unbalance of wheels and rims is of at least as great importance as is unbalance of tires, as an exciter of shimmying. Constructive work along these lines has, perhaps, been completed, but little has been heard of it; whereas, the tire has borne the brunt of the blame from the start. To stop shimmying by raising the inflation pressure is a temporary expedient only, not a fundamental cure. Such practice, moreover, defeats the purpose of the low-pressure tire, which is, to provide more comfort for the individual and lower depreciation of the vehicle. When all the five steps mentioned by Mr. Griswold as means of stopping shimmying have been given the same emphasis and constructive consideration from the standpoint of balance as has the design of a balloon tire, shimmying will again be associated principally with Terpsichore, rather than with the automobile.

Tire Standardization

J. E. Hale[31]:—In my opinion, the section of Mr. Lemon's paper dealing with the problem of tire standardization is the most important. This is essentially something for the automobile manufacturers to handle, as the public has now given approval to the full balloon tire and the industry has had sufficient experience to judge wisely between the various sizes, dimensions and constructions. The tires themselves have been properly perfected and any claims to the contrary are not justified, as is evidenced by the superior durability and lower tire-mile cost that they are rendering in comparison with the preceding types. In my judgment, any standard line-up that does not provide four-ply tires in a full range of sizes to take care of all sizes of passenger car is defective, and cannot serve as a real standard. The six-ply tire in certain sizes is apparently logical as a transition move to the final standard; but I feel that we are well on the road to proof that the four-ply large-section tire offers the most in the aggregate of comfort, appearance, traction and durability.

Furthermore, with regard to the standard, it will be a mistake to try to limit it to too few sizes, as I understand has been suggested. Such a program might appeal from a purely engineering point of view, but the original cost to car manufacturers really justifies rather small step-ups in sectional sizes, so that the assemblies can be worked out economically.

Although most of the points of tire-design technique in Mr. Lemon's paper agree with my theories, I must offer some different thoughts on tread profile. Designing tires is more or less a compromise in its various details, in order that the best all-round satisfaction can be secured; and my experience has taught me that the wide flat or shoulder profile has shortcomings that offset the benefits as outlined in the paper. I have in mind the tendency of a shoulder to cause tread separation and premature failure of the cord plies on the inside of the carcass. This shoulder localizes the flexing to such a degree that the so-called "flexing breaks" are very frequent, particularly when the tires are neglected and abused. Theory or no theory, the round-tread-profile tires are proving their own case by rendering a degree of all-round satisfaction that has not been beaten.

Mr. Lemon:—Mr. Hale's comment that the wide natural-wear-profile balloon-tire tread shows tendencies to tread separation and premature failure of the plies on the inside of the carcass because of localized flexing in the tire shoulder is not sustained by flexing angle measurements, nor by road tests. Figs. 1 and 3 of my paper indicate a decidedly reduced shoulder-flexing angle in the flat-tread tire as compared with the round-tread tire. Dissection of several hundred worn flat-tread tires has failed to reveal one instance of shoulder separation. This also applies to larger-size balloon tires that are made with six plies of cord. The flat tread strengthens the shoulder and forces the flexing to the side-wall where it belongs, according to approved technique of tire design. What probably causes tread separation at the shoulder of thick-carcass tires is extreme tread-pressure at that point, due to low tread-contact area combined with slow dissipation of the heat of flexure. The flat tread reduces the pressure all over the tread as well as the angle or amount of flexure. The larger, thinner balloon-tire effectively takes care of the problem of heat dissipation.

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FINAL REPORT ON THE 1924 CALIFORNIA AIR-CLEANER TESTS

BY A. H. HOFFMAN[32]

ABSTRACT

RAPID wearing out of the engines of farm tractors, trucks and automobiles led the University of California to undertake a study of the dust problem and the efficiency of air-cleaners in removing field and road dust from the air before it passes into the engine. Work was begun in 1922 and several reports have been made on the methods devised and the progress made during the last 2 years. Results to June, 1924, were given in the paper published in THE JOURNAL of August, 1924. The present paper gives results of the studies to the end of 1924 and includes data from tests of 12 new makes or models of air-cleaner not previously tested or not fully tested.

Of outstanding importance is the discovery that the quantity of dust inspired by any cleaner or carbureter is greatly reduced if the intake is placed high and faces away from the direction of motion of the vehicle. The cleaners on two 3½-ton Liberty trucks used in road construction work in California, with intakes located 46 and 48 in. above ground and facing forward, encountered approximately 0.07 and 0.08 gram of dust per mile respectively, whereas two other trucks of the same make and model and used in the same work, which had no air-cleaners but whose intakes were directed backward, evidently encountered much less dust as the average engine wear in these two trucks was almost exactly the same as in the truck fitted with a cleaner that caught and held slightly more than 0.08 gram per mile but which probably passed as much dust into the engine as it caught and held. A 1-ton truck which had its intake located 47 in. from the ground and facing sidewise under the hood encountered slightly more than 0.001 gram of dust. This truck, however, was used mainly on paved roads.

The makes and models of cleaner tested since the last progress report was given at the Spring Lake Meeting of the Society last June are illustrated and described and the author presents graphs showing the efficiency of all the devices tested and the amount of restriction they imposed on the flow of air to the carbureter when clean and when they had been fed from 25 to 100 grams of No. 1 standard dust, which is entirely free from moisture, has a specific gravity of 0.680, and 98.60 per cent of which passes through a screen of 200 meshes per in.

The accompanying tables give the type, weight, material and dimensions of the 12 additional cleaners tested since June, 1924, the results obtained in service tests to determine the quantity of dust entering the carbureter intake, a summary of results of tests of the 12 cleaners showing their efficiency in service runs and the amount of restriction caused by each cleaner as measured in inches of water due to vacuum in a U-tube manometer, and results of a fill-up test of these cleaners to give a general indication of how a cleaner might act if subjected to gross neglect and abuse by determining how much or how little increase of restriction occurs when from 1 to 10 lb. of No. 2 standard dust has been fed to it.

Other tests of great importance which might be made would have as their objects the determination of length of time the cleaner will last in normal service, how long it will function without attention, amount of work or time required to keep it clean and in proper working condition, weak places in its construction and variation in efficiency among cleaners of the same make and model.

The University of California is preparing a program of laboratory tests of bearing wear, which is closely allied with the dust problem. The author says that the function of the University is not to do routine testing but to devise methods and prove them by their practical application. It is ready to undertake the task in cases where the regular test methods are not applicable, as in testing radiator-fan-type cleaners.—[Printed in the March, 1925, issue of THE JOURNAL.]

THE PHYSICAL CHARACTERISTICS OF ROAD AND OF FIELD DUST

BY C. E. SUMMERS[33]

ABSTRACT

IN a study of the dust problem that has lasted more than 2 years, many observations, measurements and experiments were made to determine the nature and effect of dust and the best means for its elimination as a cause of engine wear. The results of these experiments, which seem to be of general interest, are reported, and cover briefly such matters as the chemical composition of road dust, its particle size, specific gravity and abrasive nature and the relative amounts of it to which an engine may be exposed under varied conditions. Curves are also submitted that show the average cylinder-wear on a number of test cars. The methods of testing air-cleaners are described, the principles underlying commercial air-cleaners are discussed and a list of what the author believes to be important elements of air-cleaners for passenger cars is given. —[Printed in the February, 1925, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN T. J. LITLE, JR.[34]:—Mr. Summers is not present but Mr. Lee, his assistant, will answer the questions. The first is: What is the relative amount of wear attributed to the presence of road dust and that attributed to crankcase-oil dilution?

R. K. LEE:—This problem has a number of variables that are different for every engine. From our observations we believe that, in an engine operated principally on paved roads and city streets, about one-half the total cylinder and piston-ring wear is due to the presence of dust and the remainder is caused by metal-to-metal contact that occurs when the lubricant has been washed out by gasoline during the starting process. When the engine is operated principally on unpaved roads, perhaps three-quarters of the total wear is due to the presence of dust.

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[33] M.S.A.E.—Special problems section, General Motors Research Corporation, Dayton, Ohio.

[34] M.S.A.E.—Chief engineer, Ford Motor Co., Dearborn, Mich.

When an unprotected engine is operating in thick dust, as when following another car closely on a dusty road, the rate of wear is relatively very rapid and may be more than 0.001-in. cylinder bore per 100 miles.

QUESTION:—Do coarse particles of dust cause more wear than an equal weight of fine particles?

MR. LEE:—This might be expected since the original coarse particle does a certain amount of damage in being crushed by the engine parts and continues to do damage as a number of fine particles. By "coarse particles" we mean coarse dust which would be only a few thousandths of an inch in diameter.

QUESTION:—Do you believe that engine wear is proportional to the air-cleaner efficiency?

MR. LEE:—The wear resulting from dust is practically in proportion to the quantity of dust. As pointed out previously, not all engine wear is caused by dust. Therefore, the difference in wear between using a cleaner of 98 per cent efficiency and one of 99 per cent efficiency might be too small to measure, because the 2 per cent of dust passing the 98 per cent cleaner might be responsible for only 5 per cent of the total wear of the engine. By reducing the dust to half that quantity, we would reduce the wear only 2.5 per cent. With an engine operating under dusty conditions, a change from a cleaner of 50 per cent efficiency to one of 90 per cent efficiency would reduce the wear in about direct proportion.

RATE OF DUST FEED

QUESTION:—In the road-tests, was the rate of feed of 300 grams (10.58 oz.) in 36 hr. based on any estimated running condition?

MR. LEE:—That particular wear test was made by operating the engine on the test-block.

R. E. WILSON[35]:—How did the amount of dust in the air in that test compare with estimated conditions? Was there much more than would happen under any road condition?

MR. LEE:—The rate of dust feed in the test was based on 0.25 gram per mile. We have made tests in which we followed closely another car on a dusty gravel road and found that the engine was exposed to 0.50 gram of dust per mile. The rate of feeding dust, therefore, was not so fast as dust might be drawn into an engine when operating under these conditions but it was much more than the average dust conditions. The test was made to establish some definite relation between the quantity of dust and the resulting wear. The engine tested was a standard-production four-cylinder engine of high-grade make. The wear at the top of the cylinder was 0.001-in. in diameter for every 20 grams of dust fed.

MR. WILSON:—How long was the road-test?

MR. LEE:—Many road-tests were made; the particular one referred to was a 5000-mile trip taken by four cars; about 1500 miles of the distance was dusty. Practical road-tests have been run on a number of cars covering 20,000 miles each as a basis for determining the air-cleaner efficiency necessary to protect the engine.

CHARACTER OF TEST DUST

QUESTION:—In your 36-hr. test, did you determine the maximum, mean and minimum sizes of the dust particles fed to the engine?

MR. LEE:—The maximum size was 0.005 in. and the other particles ranged from that size down.

QUESTION:—What is the standard dust used in experiments? How is it measured?

MR. LEE:—For comparative testing we have used a standardized dust prepared by Prof. A. H. Hoffman, of the University of California, which is air-floated and of very small particle sizes. Dust samples, caught in felt dust-bags under a wide range of operating conditions on the road, were examined under a microscope and the particle size was measured. It was found that average road-dust was much coarser than the dust purchased from the University of California. To make practical tests of the cleaners, it seemed desirable to use dust as nearly as possible of the same fineness that the cleaners would have to deal with when in use. The use of dust that is either too course or too fine does not indicate accurately the relative practical merits of cleaners of different types. In our tests we have used both the California standard dust and the road dust.

QUESTION:—Can you say whether the carbon on the piston is composed mostly of fine or coarse dust?

MR. LEE:—No.

W. E. KEMP[36]:—Have any tests been made to determine the quantity of dust that is expelled through the exhaust of an ordinary engine in normal operating condition?

MR. LEE:—No.

CONSIDERATIONS RELATING TO WEAR

QUESTION:—What is the size of particles recovered from crankcase oil as compared with the size of particles originally drawn into the carbureter? What is the maximum size of a harmless particle under ordinary operating conditions?

C. E. SUMMERS:—So far as we have been able to determine, road dust that enters the crankcase past the pistons is ground up too fine to cause any wear on the lower parts of the cylinder. The coarser material frequently found in the crankcase enters through the breather or consists of metal particles and core sand. These embed themselves in the babbitt and cut the journals. A dust particle ceases to be harmful when its diameter is less than the minimum thickness of the oil-film, which varies inversely as the temperature, dilution and pressure and may be very thin.

QUESTION:—Does a soft aluminum piston wear more rapidly than a hard heat-treated aluminum-piston? Also, which is better for the cylinder, a soft or a hard piston?

MR. SUMMERS:—The wear is relatively slight on pistons whether they are of aluminum or of cast iron. The wear is principally between the piston-rings and the cylinder-wall. We have no competent data on the effect of piston hardness.

QUESTION:—Does the rate of wear depend on the hardness of the surface? Does that not account for the small wear on wristpins as shown on your charts?

MR. SUMMERS:—The piston-pin is not so directly exposed to dust as are the cylinder-walls and the piston-rings. The dust lodges in the oil-film on the cylinder-walls during the intake stroke and, when the piston returns, the rings must grind against the gritty cylinder-wall. Moreover, the rubbing speed of the piston-pin bearing is much less than that of the rings against the cylinder-wall. Hardness may also be a factor in the relatively small wear of the piston-pin.

QUESTION:—What would be the advantage, if any, in a closed car, of taking the air from the inside?

MR. SUMMERS:—The air inside a closed car is usually cleaner than that under the hood, but this method possesses several disadvantages. These are (*a*) a backfire

[35] M.S.A.E.—Member research council, Standard Oil Co. research laboratory, Whiting, Ind.

[36] A.S.A.E.—Eastern distributor, Byrne, Kingston & Co., New York City.

from the engine is disturbing and may even be dangerous, (*b*) the hiss of the air through the carbureter throttle is plainly audible and disagreeable and (*c*) in cold weather the drawing of a large volume of air from the inside of the car causes a leakage of cold air around the doors, which makes the car uncomfortably cold.

Air-Cleaning by Inertia Forces

QUESTION:—Approximately, what is the size of the smallest dust particle that can be separated by centrifugal or inertia forces? What is a reasonable figure for the efficiency obtainable with very fine dust for a centrifugal cleaner?

MR. SUMMERS:—Centrifugal cleaners on the market range from 40 per cent to more than 90 per cent in cleaning efficiency when tested with actual road dust. High efficiency comes from whirling a thin air-stream at a high rate in smooth lines free from eddy currents. This allows the dust particle to find its way out of the air-stream in the minimum time and at the maximum rate. To give the air the high rate of rotation, some energy is needed, but as a good commercial cleaner must be of very low restriction, the energy required to draw the air through must be small. In the A. C. cleaner about one-half the energy in the rotating air is recovered by the reversed-spiral air-straightener. This enables the cleaner to give a practical protection of more than 90 per cent against road dust, with a very low restriction. The particles that pass through this cleaner are about 0.00012 in. in diameter.

QUESTION:—On average dust, what efficiency does Mr. Summers' cleaner give at 20 and at 40 m.p.h. on a car?

MR. SUMMERS:—Assuming an engine of average size, the air consumption at 20 and at 40 m.p.h. will be approximately 20 and 50 cu. ft. per min. respectively. The efficiency of the A. C. centrifugal cleaner having a restriction of 5 in. of water at 100 cu. ft. per min. and tested with practical road dust is 89 per cent at 20 cu. ft. per min. and 94 per cent at 50 cu. ft. per min. The practical protection given to an engine is even greater than these figures indicate, since the cleaner is positioned so that the outside of the cleaner serves as an inertia cleaner.

QUESTION:—In the composition of dust as shown, is it not true that the bulk of the silica exists as complicated silicates that are not nearly so abrasive as quartz sand?

MR. SUMMERS:—A number of combinations with silicon are present in soil. Quartz is the hardest of these, but any of them is sufficiently hard to scratch metal. Some elements in the dust are undoubtedly less harmful than others. We have found no dust samples, however, that are not abrasive; in fact, wear-tests show relatively small differences between them.

QUESTION:—In a new engine, would not the fine dust cause the most wear?

MR. SUMMERS:—Since the principal wear in an engine due to dust is between the rings and the cylinder-walls, and the rings are assumed to follow the cylinder-wall, it is doubtful whether an engine becomes particularly more susceptible to dust as it wears. In fact, it may become less so as the walls become polished so that the ring has a chance to scrape off the dust particles.

Turbulence Effects on Centrifugal Cleaners

QUESTION:—To what extent does turbulence affect the operation of centrifugal cleaners on four-cylinder engines as compared with uniform velocity at the laboratory?

MR. SUMMERS:—We have found practically no difference in air-cleaner efficiency between that of a uniform velocity and that of a pulsating flow. The source of suction in the laboratory testing-equipment, however, is a Roots blower which gives a pronounced pulsating flow very similar to that of a four-cylinder engine operating with wide-open throttle.

PRINCIPLES OF STEAM-COOLING SYSTEMS

BY N. S DIAMANT[37]

ABSTRACT

QUICK warming up, a uniform operating-temperature and slow cooling-down after stopping the engine are the objects sought and accomplished in the application of so-called steam-cooling methods to internal-combustion engines, according to the author, who asserts that engineers and manufacturers are wasting valuable time and energy on conventional methods of cooling that have some decided disadvantages instead of investigating and adopting other cooling methods that appear to present simple remedies for the cooling difficulties. He deplores the retardation of development along this line because of the involved patent situation and asserts the belief that research in this field is much more important than patents and patentees and that the latter, while entitled to fair compensation, should have enough sportsman's spirit to go ahead with their work, expecting not only such compensation but also some academic credit.

In an attempt to dispel the confusion that apparently exists regarding the underlying principles involved and the ways in which they are applied, the steam or evaporative system is described as a method of cooling in which the engine is water-jacketed in the usual way, water or a water-alcohol solution covers the cylinder-heads and surrounds the exhaust-valves at all times and is circulated thermodynamically or by a pump, heat rejected to the jackets raises the temperature to the boiling-point and thereafter vaporizes the liquid at a temperature dependent on the pressure on the free surface of the liquid, the temperature of the liquid is maintained at a definite point and no special provision is made for cooling it except that the vapor is condensed and returned to the jackets.

The author illustrates and describes the layout or disposition of the jackets, steam-chest or dome, radiator or condenser and pump or other means for returning the liquid to the jackets and maintaining the pressure under which the several systems operate. In some the steam-chest is directly above and integral with the water-jacket, and the condenser is above the steam-chest so that the vapor rises, is condensed and returned directly to the steam-chest. In others the condenser is located in front of the engine in the usual position of the radiator of an automobile. In either system a pump inserted in external piping at a point below the bottom of the water-jacket maintains pressure in the system. In other systems the steam-chest is in front of the engine and the condenser either above it or forward of it. These various dispositions of the elements of the several systems are summarized briefly for convenience.

Heat transference from the jacket walls to the liquid

[37] A.S.A.E.—Consulting engineer, National Radiator & Mfg. Co., Detroit.

is more rapid in those systems in which the rate of circulation of the liquid is more rapid. Size of pipe connections used makes little difference in operation, except that pressure in the steam-chest may be a little higher with pipes of small internal diameter.

Most of the systems described will, if designed intelligently and incorporated in the vehicles intelligently, result in as satisfactory performance of the engines in present-day cars, trucks and tractors as when they are water-cooled in the usual way, the author states.—[Printed in the March, 1925, issue of THE JOURNAL.]

THE DISCUSSION

CHARLES P. GRIMES[38]:—What gain is hoped for with the steam-cooling system, compared with the water-cooling system? I had occasion in the last few years to work with an engine that had a combustion-chamber temperature of 620 deg. fahr. when running normally under full power and full load. After working with that engine for 2 years, I reduced the temperature to 380 deg. fahr. when the engine was working at full load in continuous operation for 2 hr. in a room with a temperature of 126 deg.

It appears to me that I improved the performance to the extent of 28 hp. ÷ 24 hp. by reducing the temperature of the combustion-chamber. The temperatures of which I speak were taken at a point 1/32 in. from the inner wall of the combustion-chamber and perhaps ¾ in. above the piston travel, which point I am sure, when water cooled, is decidedly hotter than 212 deg. fahr. What you hope to gain by the steam system evidently is a rising temperature of the cylinders, but my experience has been that a reduction in temperature often gave better performance.

CHAIRMAN ALEXANDER TAUB[39]:—Is not that because the reduction was made from an extreme? Anything you might do to lower that temperature of 620 deg. fahr. would be of some benefit, but if you were using ordinary operating temperatures for water-cooled engines, such a reduction might mean too low an operating temperature.

MR. GRIMES:—Under ordinary conditions of road operation, as in summer with an air temperature of 96 or 97 deg. fahr. at 20 m.p.h., the combustion-chamber temperature was about 180 deg. fahr. I constructed a thermostatic control of the combustion-chamber-wall temperature which maintained it at 400 to 450 deg. as against the normal temperature of 180 to 250 deg. fahr. A carefully checked series of road-load conditions at speeds of from 20 to 40 m.p.h. showed absolutely no difference in the miles-per-gallon low performance other than plus or minus 2.5 deg. fahr. at the various points which averaged to zero. Suction-yoke conditions are of more importance than combustion-chamber temperatures above 200 deg. fahr.

C. B. DICKSEE[40]:—Have jacket-wall temperatures actually been measured with this so-called vapor-cooling system? It seems to me that simply by allowing a greater quantity of water to boil than normally not very much will be gained in the way of temperature increase over the ordinary method. Dr. Gibson, in England, has measured some temperatures on a water-cooled engine that had a clean combustion-chamber and jackets. He found temperatures of from 180 to 240 deg. cent. (356 to 464 deg. fahr.) on the water side of the jacket. The high temperature was in the neighborhood of the exhaust-valve. In his paper entitled Aircraft-Engine Practice as Applied to Passenger Cars[41], S. D. Heron mentioned temperatures of 450 deg. fahr. that are of the same order, measured on the water side of the combustion-chamber, in a Liberty engine. These are full-load temperatures but they will be proportional at any other load.

In the ordinary course of events the walls of the water-jacket become coated with a considerable layer of lime. When the engine is new you may get temperatures like those Dr. Gibson found but, after the engine has been used for a short time, you will get much higher temperatures. With the vapor-cooling system, the layer of lime will increase considerably because you are deliberately boiling the water away. A certain amount of water is boiled and lost with the present system but it seems to me that a greater quantity will be boiled and lost on heavy climbs with this vapor system. So I do not really see where any particular benefit accrues because, while you may get a slight increase in the temperature, the difference in the long run will amount to nothing compared with the increased complication of all this special arrangement.

WHAT THE STEAM SYSTEM ACCOMPLISHES

N. S. DIAMANT:—Before answering these questions I want to say that I am not here to advocate, defend or condemn the steam-cooling system. I am interested in it as an engineer and am glad to have the subject discussed thoroughly.

Mr. Grimes' remarks are interesting but, as the chairman has already intimated, he is dealing with an air-cooled engine. To reduce the jacket-wall temperature from about 500 to 350 deg. fahr. is evidently very different from increasing the water temperature from about 180 to 212 deg. fahr. and, consequently, increasing the jacket-wall temperature from about 230 to 270 deg. fahr.

As the last speaker stated, it would appear from theory that if the outlet-water temperature is 212 instead of 180 deg. fahr., the temperature of the cylinder-wall should not be much higher in proportion, particularly if it is considered that the suction temperature in an engine is roughly 250 deg. fahr. The compression temperature is probably about 500 deg. and the combustion temperature is 3000 deg. fahr. approximately, so that we have a temperature cycle of 250, 500 and 3000 deg. fahr., which keeps on repeating, cycle after cycle. The cylinder-wall cannot follow this cycle of temperature-change but assumes some mean temperature. What that temperature is, unfortunately, we do not know precisely and I would stimulate some real research along these lines.

As to what we can hope to gain by the vapor system, I think the best thing to do is to consider certain characteristics of present systems which we can all admit are not satisfactory. Take the pump system, for example; during the summer it will run 180 deg. fahr. at the top and, say, 170 deg. fahr. at the bottom of the engine. The thermosiphon system will run about 205 deg. fahr., with perhaps a 50-deg. temperature-drop. In winter, the thermosiphon outlet temperature will be about 180 to 200 deg. fahr. and the temperature-drop across the radiator will be 100 deg. or more, while the pump system will drop down and operate at 110, 120 or 130 deg. fahr., with a temperature-drop nearly equal to that obtained in summer. Thus, clearly, the water-temperature variation is too large. Another point is that the

[38] M.S.A.E.—Chief engineer, United Air Cleaner Co., Chicago.

[39] M.S.A.E.—Chief engineer standards department, General Motors Corporation, Detroit.

[40] M.S.A.E.—Testing engineer of light and powerplants, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

[41] See THE JOURNAL, January, 1923, p. 31.

warming-up period is altogether too long. Sometimes it is infinite and the engine never gets warm but simply comes to 110 deg. fahr. and stays there, as already stated. I am referring, of course, to engines not equipped with thermostats or shutters. The third point is that the present system cools down too rapidly.

The steam system apparently provides a simple way of attaining these three results: (*a*) quick warming-up, (*b*) slow cooling-down and (*c*) constant temperature irrespective of load or weather conditions. Other systems will accomplish these results, or new ones may be developed.

Some Combustion-Chamber Temperatures

Chairman Taub:—I have a few figures on combustion-chamber temperatures that actually were taken within 1/16 in. of the inner wall of the combustion-chamber and therefore are fairly representative. The engine was run about 700 hr. before these measurements were read, and I think we had conditions that are fairly representative. They may possibly explain why we have condensation in the winter with the ordinary water-cooled engines, as the combustion-chamber temperature was only 145 deg. fahr. with a water temperature of 110 deg. fahr.; with a 120-deg. fahr. water temperature, the combustion-chamber temperature was only 153 deg. fahr.; and with a 130-deg. fahr. water temperature, the temperature of the combustion-chamber was 162 deg. fahr.

Mr. Grimes:—What was the load on the engine?

Chairman Taub:—Full load. These are ordinary winter and fall water-temperatures. With a constant temperature of 212 deg. fahr., the top of the combustion-chamber metal was at 242 deg. fahr. Using 50 per cent of alcohol, which would drop the constant temperature to 184 deg. fahr., the temperature of the combustion-chamber metal was 226 deg. fahr. An operating temperature of 245 deg. fahr. is not one that we need be at all afraid of, inasmuch as we are evidently operating at this temperature today, during the hot weather and hard pulling. Possibly, where localized hot-spots are in evidence, the temperature of the combustion-chamber metal may be much higher.

A. W. McCalmont:—At what point were these temperatures taken?

Chairman Taub:—Immediately over the exhaust-valve in the combustion-chamber.

A Member:—If you run a system at 212 deg. fahr. and obtain certain results as against a water-cooled system at a 145-deg. fahr. outlet-temperature, why can you not run the steam-cooling system at the lower temperature? Would not the results be the same?

Ideal System Maintains Maximum Safe Temperature

Chairman Taub:—Yes and no. First, you have to accomplish the running of the steam-cooled system at 145 deg. fahr. It can be done, but it would be necessary to introduce a vacuum. Secondly, as the operating temperature goes down the friction goes up. The ideal steam-cooled system is one that maintains the maximum safe operating temperature.

A Member:—When you do run at the lower temperature the engine horsepower increases. As an instance, a certain car carrying a certain load and with a conventional water-cooling system, climbed the Fort George Hill in New York City at 22 m.p.h. Switching over, and working on a vacuum that reduced the boiling temperature to 140 or 145 deg. fahr., the car climbed the hill at 33.35 m.p.h., all else remaining the same. By reducing the temperature the horsepower was increased.

In this actual case, the water temperature was held at whatever vacuum we had, not varying more than 1 deg. fahr. on either side of the point determined upon, and the engine was made to run at that temperature and can be made to run at that temperature all day, week in and week out. The system can be a true vacuum temperature-control; it can be set at any point desired, 150, 160, 170 or 180 deg. fahr., or only slightly under boiling. It will not have a tendency to raise the temperature like the systems that have been described here, which simply run at atmospheric pressure. Would not something like that be more satisfactory than a system in which the change would be considerable?

Chairman Taub:—Anything would be more satisfactory that was more simple, but I cannot conceive of any system in which you could continue to introduce a vacuum without introducing mechanical and operating complications. You cannot isolate engine performance and the cooling system together. Other elements are present, such as the quantity of heat applied to the exhaust-manifold. In going to a higher operating-temperature you are merely converting an already existing water-cooled system and are using a heated manifold that is heated to rather an excess. When you increase that temperature you have to drop the heat on the manifold or you are certain to have a loss in volumetric efficiency. The steam-cooled job does not require exhaust heat to the extent of the ordinary water-cooled job, and if that change is not made you naturally would lose, just as you would lose if you increased the quantity of heat applied to the manifold.

A Member:—In this particular case the acceleration was very much greater and the economy of the carbureter was better, besides the increase in horsepower.

Practical Application to Present Engines

Arthur A. Bull[42]:—It appears logical that if the steam system provides for uniform operating temperature both summer and winter and also provides an economical operating temperature under the varying load conditions with which we are experiencing most of our troubles, it is worthwhile to consider it. On the other hand, immediately an increase in the operating temperature is suggested by such means as described, one wonders whether such an increase in the temperature is practicable. Why should the operating temperatures of an internal-combustion engine be limited to the boiling-point of a particular fluid that is used as a heat-transferring agent?

I question whether some of the systems described could be applied practically and be successful with present engine constructions, as the increase in the operating temperatures would naturally bring about conditions of unequal expansion and improper valve operation and affect detonation. Immediately we arrive at a temperature exceeding the boiling-point of water those conditions arise. While I am not advocating a compromise system in the face of the possibilities of other means of cooling, air for example, I do say that it is entirely practicable, all conditions being right, to operate without difficulty at considerably higher temperatures than those to which we are now accustomed.

J. S. Erskine[43]:—We are all more or less familiar with the hopper-cooled farm engines that operate at a water-temperature of 212 deg. fahr. Several years ago the Fairbanks-Morse Co. built a number of electric-light

[42] M.S.A.E.—Chief engineer, Northway Motor & Mfg. Co., Detroit.

[43] M.S.A.E.—Chief engineer, gas power laboratory, International Harvester Co., Chicago.

plants having a small radiator above the hopper which acted as a condenser from which the water ran back into the hopper. That was a steam-cooled outfit.

If an engine were made with only the steam condenser and the water were simply allowed to come to a temperature of 212 deg. fahr., what would be the effect on the design of the cooling chambers? It seems to me entirely possible, with a suitable design of the water passages and the cooling space, to build an engine that would operate without any pump circulation and the radiator would be used simply as a condenser for the steam formed. Would the water passages have to be enlarged to any considerable extent?

Higher Temperature Increases Mechanical Efficiency

MR. DIAMANT:—The problem is complicated and I cannot answer the question any more definitely than to say that it would be well to enlarge the water passages in the jackets and to avoid pockets. Many wish to take an ordinary engine, change the cooling system and run it satisfactorily, but some will find that as they increase the water temperature the horsepower will go up; others will find that the horsepower of the engine will go down. Some engines have one characteristic; others have another. Thus, one speaker states that the engine horsepower increased with an increase in the water temperature, while another speaker states just the opposite. They are both right. It is necessary, to explain the reason for this, to analyze and determine the effect of the water-jacket temperature on the volumetric efficiency, on the mechanical efficiency and on the thermodynamic efficiency of the engine. However, without going into great detail, it can be stated that as the water temperature is increased the piston friction and also the volumetric efficiency will be reduced. Considering only these two major factors, we see that as the water-jacket temperature is increased the mechanical efficiency is improved while the volumetric efficiency is reduced; if the increase in power output due to the improved mechanical efficiency is 3 hp. and the loss in horsepower due to the smaller volumetric efficiency is 1 hp., the net result will be a gain of 2 hp., and similarly for other cases.

P. H. SCHWEITZER[44]:—I think most of us realize and appreciate the potential advantages of a steam-cooled internal combustion engine. Why do we not have it? Experimentation has been going on for several years. I would like to hear what difficulties Mr. Diamant encountered. Did he find any difficulty in keeping the steam in the system? Is it necessary to seal the whole system to prevent escape of the steam and too frequent fillings with water?

No Loss of Steam

CHAIRMAN TAUB:—To operate a steam-cooled job in the maximum air temperature without any loss of steam is perfectly feasible. In the early history of steam-cooled systems some difficulty was encountered because of lack of knowledge of proper venting, but since then it has been found possible to run the vent through a part of the radiator so that it comes into direct contact with the air, and the little steam that might get by is condensed. The loss of steam is absolutely nil. We had one steam-cooled car that was driven from Los Angeles to Detroit and had Los Angeles water when it arrived.

MR. SCHWEITZER:—Are there any other other technical difficulties?

CHAIRMAN TAUB:—I do not know of any, they are more commercial than technical.

F. M. YOUNG[45]:—The chief trouble is getting the steam into the radiator. The trouble is not with the steam-cooling system but, with the automobile. The radiator is down low and to introduce the steam into the radiator or condenser you have to bring it in very low. You cannot do that unless you build a car like a Renault or a Mack truck.

Mr. Erskine referred to the Fairbanks-Morse plants. I conducted those tests and the company with which I am now connected has built about 12,000 of those units. They are working successfully. That job was developed between our company and J. C. Armstrong, of the Fairbanks-Morse Co. We took the manifold off the top of the engine and put our core on top of that; of course the steam rose. We do not even seal the top, we have no vent and we do not lose a drop of water. We do not get any coating as in a hopper-cooled engine.

Where the steam-cooling man is crippled is in getting his system on the car as it is built today. The problem seems to be to get the steam into the condenser or the radiator and accomplish it by using the present type of construction.

Conventional Cars Successfully Steam Cooled

CHAIRMAN TAUB:—Numerous cars that I know of personally are steam cooled and have conventional radiators in the same old place. These cars were built by ordinary mechanics and they incorporate nothing special. So I think we might as well forget that part of the picture. The steam can be brought in any one of several ways or it can be run direct.

MR. YOUNG:—In that case you have to use a mechanical agent of some kind to get it into the radiator.

CHAIRMAN TAUB:—I believe that the simplest way is the best; it is merely to let the water come to a boil, with the steam that is formed passing directly from the head into the top of the radiator and from there down through it.

L. C. FREEMAN:—What is the effect on the efficiency of the condenser of the degree of dryness of the steam that is supplied to it?

MR. DIAMANT:—Suppose that 1000 B.t.u. per min. is rejected from the combustion-chamber into the jackets. This heat goes into the jackets and it is immaterial to the engine how it is dissipated so long as it is done properly. If this 1000 B.t.u. per min. is used in the formation of dry steam, it will require about 1 lb. of steam to absorb it, so that at the end of 1 min. we shall have 1 lb. of water at 212 deg. fahr. at the bottom of the condenser. But with the same engine running under the same conditions and rejecting 1000 B.t.u. per min. into the jackets, if the quality of the steam drops to 80 per cent, then we shall have 0.8 lb. of steam in 1 lb. of water; and this will account for about 800 B.t.u. The remainder of 200 B.t.u. per min. will have to be absorbed by cooling the water from 212 deg. to 12 deg. fahr., which is practically impossible in this particular case without a refrigerating room. Therefore, if instead of 1.00 lb. of water, which was really originally 80 per cent steam and 20 per cent moisture, we have 1.25 lb. of steam, this will take care of 1000 B.t.u. per min. and the temperature of the condensate will be 212 deg. fahr. as before. Now, the efficiency of the radiator to condense 1.25 lb. of steam having a quality of 80 per cent will be practically equal to its efficiency to condense 1.00 lb. of dry steam. If the

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[45] M.S.A.E.—Vice-president and general manager, Racine Radiator Co., Racine, Wis.

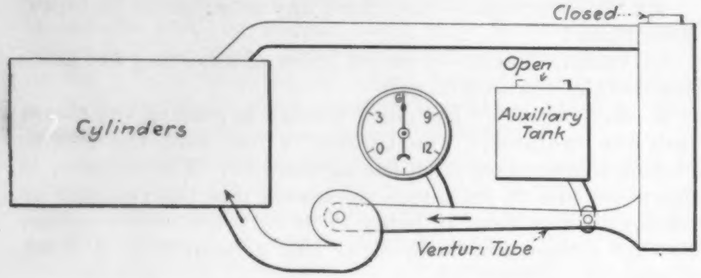

FIG. 12—LOOMIS PRESSURE SYSTEM FOR INCREASING BOILING TEMPERATURE

The Pump Circulates the Water in a Closed System and the Restriction in the Venturi Tube Increases the Velocity of Flow from the Radiator and Raises the Pressure on the Suction Side of the Pump

quality of the steam is unduly reduced, the efficiency of the condenser will be reduced slightly.

THE DANGER OF HOT-SPOTS

H. A. HUEBOTTER[46]:—I can see three outstanding advantages in vapor cooling. The first is the better stability of the engine operating-temperature under all atmospheric and load conditions. Another which is apparent is that we should be able to dispense with a fairly large proportion of radiation surface since, in the vapor-cooling system, we shall have an average temperature in the radiator of more than 200 deg. fahr. while in the water-cooling system we shall have an average temperature of about 160 or 180 deg. fahr. The difference in temperature between the radiating surface and the atmosphere is the measure of the area necessary to radiate all the heat absorbed by the water-jacket. That is rather important because of the reduction of head resistance and also of the first cost of the radiator.

Another advantage is in the reduced size of the water-circulating system. If the ordinary automobile circulates from 30 to 40 lb. of water per min., the steam-cooling system probably will not circulate more than 3 or 4 lb. per min. That permits the use of a smaller circulating pump and smaller manifold and results in lower weight.

However, there are some disadvantages. We know from our work on high-compression engines that we must be very careful to dissipate the heat at certain important surfaces inside of the combustion-chamber, especially at the exhaust-valve seat and the spark-plug boss. If we rely upon ordinary convection currents there will not be enough turbulence in the water to give sufficient scouring action on the metal. We must not lose sight of the fact that we shall run into considerable trouble in conveying the heat from the metal of the combustion-chamber walls to the cooling medium if we reduce the rate of circulation of water about those important points.

E. W. WEAVER:—Has Mr. Diamant ever given any consideration to the use of the vapor-cooled system with the aircraft powerplant?

MR. DIAMANT:—I have done no work on aircraft engines but the last system I showed, Fig. 5 of my paper, has been used for aircraft work. The difference between the automobile engine and the aircraft engine is slight so far as cooling is concerned and, therefore, the application of steam-cooling to aircraft engines should not prove difficult. However, some work done at the Bureau of Standards seems to indicate that the factor of safety for high-compression engines is reduced when the temperature of the water-jacket is increased. Thus, if the water temperature of an aircraft engine that operates satisfactorily without detonation at 180 deg. fahr. is raised to 212 deg. fahr., one may or may not get detonation; but, in either case, the factor of safety apparently will be reduced.

In this connection, I may add that, although I have shown seven forms in Figs. 1 to 5 of my paper, many other forms are possible by properly combining the items given under the heading Summary of Various Steam-Cooling Forms[47]. Thus, Fig. 4 of my paper shows the form adopted by Rushmore and described by P. M. Heldt in an article entitled A New Method of Cooling Automotive Engines[48]. The novelty of this form consists in having the vapor chest or vapor dome below the cylinder-head, and in analyzing its characteristics this fact must be given consideration.

MR. WEAVER:—The point I wanted to bring out is that, with aircraft, you are not nearly so limited in the possibility of placing the radiator higher as with the automobile.

TEMPERATURE RAISED BY PRESSURE SYSTEM

MR. GRIMES:—Mr. Loomis, of McCook Field, conceived the idea of building-up the pressure in the aircraft radiating system. It was possible to raise the pressure as much as 2 or 3 lb. per sq. in. by causing the water to circulate from the pump in a closed system. That is not really a pressure system, but I think Mr. Loomis's idea was to increase the pressure to prevent rapid evaporation of the water at altitude. Perhaps that system might be a compromise between the water system and the vapor system. The Loomis pressure system is illustrated in Fig. 12.

I built the Venturi tubes and set up the first test equipment for Mr. Loomis on a Liberty-12 engine. We demonstrated a pressure of 6 lb. per sq. in. at a point 6 in. ahead of the pump on the suction side. This pressure can be increased by proper design and the pressure will raise the temperature of the boiling-point of the water.

C. W. FREDERICK:—A point was raised a while ago about hot-spots in engines around the exhaust-valve seats and the spark-plugs. Some trouble has been experienced with excessive heating when a steam-cooled engine is run for a long time at full load; certain parts seem to get hot and cause a drop in power. Has anyone taken up that problem and got rid of the heat in a steam-cooling system?

MR. SAUNDERS:—We have had trouble on various commercial jobs because, while passages were provided for the circulation of water around the exhaust-valves, the resistance to flow was so high that the circulation was very slow. Hot-spots would be present and give trouble. The remedy was to correct the cylinder gaskets.

MR. HUEBOTTER:—With regard to the rate of circulation about the exhaust-valve seats, my experience has been that if we have any defect in the water-jacket casting our first trouble is in the burning of the exhaust-valves. That is noticeable especially in tractor work, where the average load is high. If the foundry lets a fin form inside the water-jacket, steam pockets are generated around the exhaust-valve seats, resulting in an absolute stoppage of flow there, and the exhaust-valves begin to deteriorate rapidly.

We might try steam-jacketing the lower half of the crankcase in winter to eliminate the trouble due to oil dilution, instead of having all the condenser surface at the front of the car. If we could keep the crankcase at a temperature of 212 deg. fahr. we might volatilize all

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[47] See THE JOURNAL, March, 1925, p. 333.

[48] See *Automotive Industries*, May 26, 1921, p. 1103.

but the very heavy ends of the gasoline and also reduce the viscosity of the oil and help its circulation.

Increased Turbulence Prevents Hot-Spots

Chairman Taub:—One of the reasons that we experience trouble with the ordinary type of water circulation when the casting contains a bad fin is because the means of cooling is really the convection caused by the velocity of the water around critical spots. When that is misdirected by a fin or some other blunder in the foundry, that system fails; whereas, in the case of steam-cooling, each spot takes care of itself.

Some places are harder to cool than others, such as the exhaust-valve as compared with the intake-valve, but more turbulence is to be found at that particular hot-spot, more bubbles. Far more agitation is caused by boiling than can be caused by any pump that I know of that is used today. A great advantage of steam cooling is that, all through the engine block, the turbulence depends entirely upon the temperature of the parts being cooled and in this way the hot-spots take care of themselves; they do not become evident.

Mr. Huebotter:—The increased ebullition at those places would help the turbulence; but, on the other hand, the better currents for convection of heat would be much more effective than the boiling turbulence in washing the heat from the metal.

Chairman Taub:—That has not been our experience. We get local hot-spots even in the so-called best water-cooled cars, but do not get local hot-spots in the constant-temperature engine. One of the most interesting things I have noticed in this connection is that uniformity of cylinder temperature is not a function of the uniformity of the temperature of the cooling medium. If you try hard enough you may succeed in getting the minimum of 5-deg. fahr. temperature-difference throughout the jacket, yet a 25-deg. fahr. actual temperature-difference of the iron will be found in like places in the block. That applies particularly to water-cooled temperatures up to 145 deg. fahr. As the operating temperature is raised and approaches 205 deg. fahr., the temperature of the iron becomes more uniform and at 212 deg. fahr. it is uniform. A uniform method of cooling coupled with the uniformity of higher temperature gives a very fair condition.

Mr. Huebotter:—That would be true if all the combustion-chamber surface were transferring heat at the same rate, but the rate of heat passage through the metal depends largely upon the rate at which the metal receives the heat. At the points where the flame and the hot gas are in most violent turbulence, the heat transfer to the metal is most efficient. Gas passes through the open exhaust-valve at a mean velocity of probably 250 ft. per sec. and, since the turbulence is very high at that point, the rate of heat transfer is high. Not only that but when the exhaust-valve is closed it must dissipate through the seat all the excess heat it has absorbed during the time it was open. That is, instead of 4 B.t.u. per sq. in. per min., which is a fair average for the entire combustion-chamber, the exhaust-valve seat is probably receiving from 6 to 8 B.t.u. per sq. in. per min. We cannot hope to dissipate that excess heat by simple convection currents. Some very free passages must be provided and, I would say, preferably forced circulation at those points. Our experience has been that the exhaust-valve temperature is one of the main things that determine the maximum allowable compression-pressure of the engine. That, in turn, affects the economy of the engine because it limits the degree of expansion that can be allowed the gas after combustion takes place.

Mr. Dicksee:—To illustrate Mr. Huebotter's point, I quote some temperatures from an air-cooled engine. The temperature near the inlet-valve seat was 105 deg. cent. (221 deg. fahr.) while the temperature in the neighborhood of the exhaust-valve seat was 250 deg. cent. (482 deg. fahr.). The airflow over those two spots was exactly the same, as the finning arrangements and the air velocity are the same in both cases. These temperatures are a measure of the relative heat dissipation from those two points.

Chairman Taub:—I think the cases are not similar. If you could construct an air-cooled engine in which you could keep the air dancing around the hot-spots so that its particular velocity would increase with the temperature increase, you would have a condition that would be somewhat similar to that of a steam-cooled engine. When a spot is particularly bad, that spot is doing more work in transferring heat. In my previous remarks I was merely talking about uniformity of like positions; for instance, it is fair to assume that the temperature of No. 1 exhaust-valve and No. 6 exhaust-valve on a six-cylinder engine should be of similar degree. In a water-cooled engine that is not the case, even though the temperature of the water around those particular places may be within 5 deg. fahr.

I have some figures here on a water-cooled engine that actually was fussed with until we were able to maintain 170 deg. fahr. with the inlet water at 165 deg. fahr. The difference was only 5 deg. fahr. between the hottest and the coldest water in that block, yet the exhaust-valve-seat temperature was 249 deg. fahr. When this same engine was steam cooled, the temperature at that point was 250 deg. fahr., only 1 deg. fahr. higher, which is certainly within the allowable error of a thermocouple as we know it.

Mr. Diamant:—What was the rate of circulation of water in the two cases?

Chairman Taub:—When the engine was steam-cooled no water was circulated, the only water that passed into the condenser was that which was carried over by the steam. When it was water cooled, the circulation was 80 lb. of water per min.

A Member:—We have found that water-cooled engines will operate satisfactorily with 5 lb. of water per hp. per min. You get no temperature difference at all with the steam-cooled engine going down to 1.5 lb.

Some Facts To Bear in Mind

Mr. Diamant:—We will make more progress in this discussion if we keep some physical facts clearly in mind. When we talk about steam-cooled engines, it is understood that there is no free steam in the jackets; the cylinders are water-jacketed as usual. Also, when we consider the question of the temperature of the jacket metal, we are dealing with conduction of heat and not convection; the laws of conduction are very different from those of convection.

Mr. Dicksee:—Another point we should bear in mind is that if any modification is made in the cooling system we may be trading with the exhaust loss. If the amount of heat carried away by the cooling system is decreased, the amount of heat carried away by the exhaust system is correspondingly increased without affecting the heat appearing as useful work. This is true over a considerable range. So, whether we are using the steam-cooled system or the water-cooled system, unless a proper heat balance is struck, figures cannot be compared with any degree of satisfaction.

A MEMBER:—As an instance, during one test the water in the jackets was very low; in fact, only 1 gal. of water was in the whole system. That left the cylinder-heads exposed rather far down. During that test, which ran for 2 weeks, nothing outside of the ordinary performance developed. If any warping of the valve-seats occurred, it did not become apparent. The only thing that was noticeable was that, instead of condensation taking place in the line across the top, it was simply farther down in the radiator, showing that the rate of steam generation was much higher than under ordinary conditions. That may explain why valves may not tend to warp. While the latent heat of steam is not the same as that of water, it will simply take a greater quantity of steam to do the cooling that the water ordinarily would do.

CHAIRMAN TAUB:—We also had an accident: When we were expecting 80 per cent steam and 20 per cent water, we were getting 100 per cent steam. We found that the water-level was even with the split between the head of the block and the cylinders; it was an L-head engine. Still, the engine was pulling within ½ lb. of the maximum pull.

A MEMBER:—In our case the water was perhaps 3 in. below the split between the cylinder-head and the jackets. That engine also ran with oil instead of water and gave a very creditable performance.

CHAIRMAN TAUB:—How did you maintain your low temperature?

A MEMBER:—With a vacuum.

CHAIRMAN TAUB:—At what temperature did you operate?

A MEMBER:—At about 180 deg. fahr., with water. When oil was used the temperature was about 140 deg. fahr. That was not only the temperature of the oil in the system but also the temperature in the steam jacket of the oil vapor that was coming off.

CHAIRMAN TAUB:—What vacuum were you using?

A MEMBER:—In the neighborhood of 25 in.

COMPARISON WITH THERMOSIPHON SYSTEM

MR. HUEBOTTER:—While considering the relative effect of steam or vapor-cooling and of ordinary water-cooling on exhaust-valve temperatures, we must realize that not all water-cooled engines have effective jackets about the exhaust-valve seat. If we study some water-jacket castings it will be seen that the exhaust ports are surrounded by water which has circulation only by its own thermosiphon action. In steam-condenser practice the coefficient of heat transfer is affected considerably by the rate of flow of water; a higher velocity will materially increase the rate at which heat is transferred from the condenser tubes to the condenser water.

A. F. MOYER[49]:—Can someone explain what real difference exists between some of the steam-cooled systems and a thermosiphon system? The temperature at the top of the radiator in the thermosiphon system is frequently as high as 205 deg. fahr. I think without any question that the water in the jacket of the engine is not of uniform temperature throughout the various parts of the jacket, that the water next to the metal wall at the top is hotter and may easily reach 212 deg. fahr. The rapid circulation established in the thermosiphon system is due, I believe, to minute steam bubbles next to the metal surface, which subsequently condense and reach the radiator. If those bubbles are formed in the thermosiphon system, what is the difference if more of them are formed and pass on as steam?

CHAIRMAN TAUB:—The only difference is that, with the thermosiphon system, the engine is hot in summer and cold in winter. What we are endeavoring to accomplish with the steam system is to have a temperature that is satisfactory all the year round.

G. L. MCCAIN[50]:—The main question is not whether an engine is steam-cooled or water-cooled but how to control the water and hold it. With the ordinary pump system, steam bubbles form and force most of the water out and, even though baffle plates are resorted to, part of the cooling medium is lost. With the thermosiphon system about the same thing occurs, the water boils and the bubbles carry the water out through the radiator and an overflow follows. It is largely a matter of controlling the steam so that it stays more or less stationary in the water and maintains a uniform temperature rather than a question of whether the temperature should be 249 or 250 deg. fahr.

CHAIRMAN TAUB:—It is exactly that; merely determining what the ideal operating temperature is and maintaining it, and retaining the fluid for the longest possible time.

E. A. COUSINS:—You say the difference was only 1 deg. fahr. How did the exhaust-gas temperatures compare? I assume the conditions were the same in the two tests.

CHAIRMAN TAUB:—No change was made in anything but the connections to the water system; the conditions were the same within an ounce. When an ordinary water-cooled car is run in the summer, temperatures of 209 and 210 deg. fahr. are sometimes reached but, so long as the water does not boil, you are satisfied. The only reason you stop when the water boils is because the car will be out of water very soon. Conditions are not different when operating an engine with steam-cooling, except that proper provision has been made for the dynamic action of the water. In an ordinary water-cooled engine you have convection, and should have approximately 80 per cent of the water flowing on the valve side. With the steam-cooled engine you just stick the hose in wherever you can find room and let it go at that; and it takes care of itself.

L. A. CHAMINADE[51]:—One speaker asked for the essential difference between the thermosiphon and the steam systems. The difference is that, in the thermosiphon system, the water at the bottom of the jacket is at a temperature of about 155 deg. fahr. and that at the top is about 205 deg. fahr.; whereas, with a steam-cooled or vapor-cooled system, the difference in temperature between top and bottom will probably be only 4 or 5 deg. fahr. In a pump-circulation system in which the flow of water is rapid, the temperature between the top and the bottom, presumably in the engine as well as in the radiator, has a difference of 8, 9 or 10 deg. fahr.

Another speaker told of his experience in running the water in the jacket too low and having no trouble with it. The assumption from that is that no damage will be done to an engine if the water is low. We all know of plenty of cases in which cars have been run from 6 to 10 miles in the winter with practically no water, but those cars were very close to the danger point. We have learned in experiments with cast-iron and aluminum cylinder-heads that the water-level makes a difference. In those experiments we purposely cut the level down to about 2½ or 3 in. from the bottom of the jacket to determine whether aluminum heads were as safe as cast-iron heads, particularly in desert country when the

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[50] M.S.A.E.—Automotive engineer, Link Belt Co., Detroit.
[51] M.S.A.E.—Mechanical engineer, Studebaker Corporation of America, Detroit.

water gets low. The tests were run on the dynamometer at speeds and loads corresponding to 15, 25 and 35 m.p.h. of the car in which that engine would be placed.

As I recall, the test at 15 m.p.h. was to run ½ hr., at 25 m.p.h. for 20 min., and at 35 m.p.h. for 15 min. The water was about 1.5 in. below the split between the cylinder and head, but water circulation was maintained by the pump. The cast-iron heads went through the test absolutely all right, so far as we could see; we had no trouble with a single one. When the aluminum heads were tested not one went through the 25-m.p.h. test without the top of the combustion-chamber's becoming so hot that the mechanical structure of the aluminum was completely shattered; the head was simply blown right through. Therefore, you are very near the danger point with cast-iron heads when the water is too low.

Combustion-Chamber Covered by Water

CHAIRMAN TAUB:—I hope you do not think that any-one is trying to advocate an engine in which the top of the combustion-chamber would be exposed.

MR. CHAMINADE:—No, but I do want to point out that it would be impossible to cool an engine by steam alone.

CHAIRMAN TAUB:—That is one of the unfortunate things about this discussion. The system is repeatedly referred to as "steam cooling." Steam does not cool at all; we have to get rid of the steam; all the work is done by boiling.

MR. CHAMINADE:—If the engine is steam cooled, is there water in the jackets around the cylinder and combustion spaces and is it heated until steam comes off the surface of the water?

CHAIRMAN TAUB:—The water-level in the steam-cooled engine is exactly the same as that in the normal water-cooled engine. If a dome is allowed for, it is above that point; it is additional space and that type of head would be higher, but the water-level is exactly the same. Cooling is done by the change of water to steam and not by the contact of steam with the combustion-chamber.

Radiator More Efficient as a Condenser

MR. DIAMANT:—"Steam cooling" is an unfortunate term and it is well to remember that steam will give off its heat very rapidly. As Mr. Huebotter brought out, the amount of heat transferred from water to metal depends on the velocity of the hot water. The higher the velocity, the higher will be the rate of heat transfer. The rate of heat transfer from steam to metal by condensation is slightly higher than the rate of heat transfer obtained from the highest rate of water circulation. Thus, when we attempt to use an ordinary radiator to condense the steam given off at the free surface of the water which covers the engine jackets, we take advantage of the greater efficiency of the radiator as a condenser over that of the radiator as a water-cooler. If we wish to cool an engine by blowing steam through the jackets, we shall find that heat transfer from hot steam to cold metal is several thousand times greater than the heat transfer from hot metal to steam that is at a lower temperature than the metal. Therefore, if you attempt to cool an engine by steam, that is, if you introduce live steam into the jackets, you will have trouble; you might as well introduce air into the jackets to cool them. In fact, roughly speaking, the coefficient of heat transfer of air and steam is about the same, when the temperature of steam is raised, but the coefficient of heat transfer for steam is entirely different when cooling from steam to water; that is, when condensing. In the latter case, the rate of heat transfer is the same as that obtained with the highest rate of water-flow, while in the former case it is practically the same as the rate of heat transfer for air.

It is very gratifying to see so much interest shown in steam-cooling systems. Our present water-cooling systems seem to have two great advantages, in that they work well and are fairly easy to design. These are important advantages but the systems also have serious faults, which are getting more serious as the volatility of the gasoline is decreasing and as the question of crankcase-oil dilution and other similar questions are coming to the front. Further, engines are being improved and refined and scientific research is being used more and more extensively. We are discovering the weak points of our present cooling systems; that the water temperatures in the various parts of the jackets vary considerably; that the temperature distribution in the engine block is far from uniform; and, in some instances, that the factor of safety is not large enough. Engines have withstood the chronic chills and fevers to which they have been subjected for years but engineers and the public are being educated to a point where it will be necessary to improve present systems by thorough systematic experimental work so that we can offer the public something new, something better, something that has been tried and perfected.

MEASUREMENT OF ENGINE VIBRATION PHENOMENA

BY C. E. SUMMERS[53]

ABSTRACT

SMOOTH operation of motor cars becomes increasingly important as average driving-speeds become higher and as the public demands greater luxury and freedom from vibration. An analysis of vibration shows that it is caused by forces which can be calculated with considerable accuracy. Vibration itself is very complex, due to the inter-relation of forces, deflection and periodicity in the parts of the engine. In this paper a number of indicating and recording instruments devised for recording the actual resultant vibration and determining its exact character, are described and their operation explained. Vibration due to unbalance of rotating parts, piston unbalance inherent in four-cylinder engines, bending of the crankshaft, centrifugal force and torsional periods are discussed. Indicator-diagrams of the various kinds of vibration are shown.

Unbalanced force and elastic reaction are the two general causes of vibration. The former includes static and dynamic unbalance of reciprocating and rotating parts, while elastic reaction includes bending and twisting of the crankshaft and crankcase caused by centrifugal forces of unopposed masses and uneven turning-effort. The amplitude and frequency of torsional vibrations can be calculated from indicator-diagrams made by the new instruments. Half of all

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vibration in motor cars is due to simple unbalance of rotating and reciprocating parts and as much care should be given to balancing pistons, connecting-rods, flywheel and clutch as to balancing the crankshaft. Four-cylinder engines are inherently unbalanced and when the vibration impulses come into step with the natural period of the chassis on its springs, a period of large amplitude results. In an engine operated at full load and slow speed, explosion pressure causes downward deflection of the crankshaft, and this effect is practically doubled when detonation occurs. Centrifugal forces, although balancing one another, are in different planes and introduce bending stresses in the shaft which are transmitted to the crankcase. Deflection caused by the dynamic centrifugal force is twice that caused by equal static force. The crankcase has its own period of vibration and bending increases as the square of the speed, so that it becomes significant only at the higher speeds.

The crankshaft tends to wind and unwind under intermittent turning-efforts, the degree varying with the stiffness of the shaft, the inertia of the pistons and the mass of the flywheel. It therefore vibrates torsionally at a definite frequency which, at some definite speed, falls into step with the natural rate of vibration of the shaft assembly. When the period is determined for one rate of rotation, it can be calculated for all other speeds. The frequency of vibration ranges from 180 to 250 cycles per sec. and the amplitude ranges from 0.01 to 0.03 in. at crankpin radius at normal speeds.

It is not desired to emphasize the importance of vibration unduly, as the most smooth running engine may not be entirely free from vibration in some of its forms and even a rough engine may not be seriously objectionable to its owner. However, undue vibration must be overcome and progress is being made by a better understanding of its causes, so that eventually an engine that is free from vibration may be more cheaply built than one in which vibration occurs.—[Printed in the February, 1925, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN H. M. CRANE[53]:—I think you will realize, from the illustrations shown by Mr. Summers, the force that builds up by repeated small increments. I can testify that it is there, from an involuntary experiment with a large six-cylinder engine of about 563-cu. in. displacement. It had a very rigid crankcase and seven main bearings and rigid throws. The crankshaft was 2 in. in diameter, and the pins and the bearings were highly heat-treated Krupp chrome-nickel steel having a scleroscope hardness of about 60, with an elastic-limit, probably, of more than 100,000 lb. per sq. in. An attempt to drive gears from the front end of that shaft met with a vigorous protest from the gears. By one of those strategic retreats that we have to make from time to time, we moved them to the rear end of the crankshaft. This protected the gears all right, but the engine then proceeded to break off the crankshaft just ahead of the last main bearing; it was the most perfect fatigue fracture you ever saw and was entirely the product of the torsional period in the shaft.

That period was very noticeable at 42 m.p.h., which in that case would correspond to about 1200 r.p.m. of the engine and was sharply defined. The car would go through the period in 2 miles, going in and out again between 41 and 43 m.p.h. The present size of crankshaft that we are all using is beyond the danger of any such happening but is not beyond the other difficulties.

Mr. Summers' paper contains considerable interesting matter and we want to get the best we can out of it in the way of discussion.

W. R. GRISWOLD[54]:—At the Packard plant we have attacked this problem from a purely mathematical angle and have arrived at about the same conclusions as Mr. Summers. Calculation of the critical speeds is comparatively simple, once a few of the quantities are known or found out. Sometimes, when we have slight knowledege of the quantities or magnitudes involved, we get excited about little things that are really of no consequence so the first thing to do, in starting any research of that kind, is to get some idea of the magnitudes. When these are determined, it is easy to eliminate those that are of comparatively little importance. That is what we did at the Packard Company, and we have been able to reduce the calculation of torsional speeds to a simple graphical method. It is a combination of various methods that were advanced some years ago, particularly by the German and French writers.

Some time ago F. M. Lewis advanced a solution[55] for calculating critical torsional speeds which is very accurate; that is, the critical speeds can be estimated directly from the drawing-board with good accuracy. However, his method involves considerable calculation and it is a long, tedious job to get a result.

On the other hand, two German writers named Kurtzbach and Gümbel have developed some rather simple methods of a graphical nature. The data given in their papers, however, do not apply to specific problems. Practically all of the treatment is general in character, so we proceeded to reduce the treatment to a basis that permitted its use in automobile work. By reducing the German method to a comparatively simple one we have been able to determine, practically, with certain types of crankshaft, while the engine is on paper, just where the critical speeds will be and we are now working on a method of determining the approximate amplitude of the smaller vibration.

J. H. HUNT[56]:—I would like to suggest that Mr. Griswold present, either in written discussion or as a paper, the method of approximation that he has found effective. This problem is so intricate and a complete mathematical solution is so tedious that no automobile engineer is likely to make the calculations. It is always possible to eliminate a number of factors in any machine, as Mr. Griswold has pointed out, if you know what you dare eliminate, and so arrive at a mathematical conclusion that is sufficiently close to the correct solution for all practical purposes. In view of the fact that no discussion is available in the English language which would confer that knowledge upon us, he would confer a great benefit on the members of the Society if he would contribute that information at some time.

QUESTION:—You stated that a front-end flywheel of a certain size is beneficial. How is the vibration period affected when two flywheels are used, one at either end of the shaft? Does a divided flywheel, that is, one at the rear and one at the front, help to eliminate vibration?

C. E. SUMMERS:—If we take an otherwise conventional shaft and put a flywheel at the front end and measure the vibration, it will be observed that the amplitude is greatly increased and the vibration frequency is slower. If we add inertia at the front and take it off at the rear, as those who use front-end flywheels do, I think we will derive a benefit, because we practically divide the shaft. We might have a node at the middle and a vibration of

[53] M.S.A.E.—Technical assistant to president, General Motors Corporation, New York City.

[54] M.S.A.E.—Engineer in charge of analysis of design, Packard Motor Car Co., Detroit.

[55] See THE JOURNAL, November, 1920, p. 418.

[56] M.S.A.E.—Head of electrical division, General Motors Research Corporation, Dayton, Ohio.

large amplitude but rather slow. The limiting thing, I have found, is that it is possible to feed a vibration back through the transmission, if we go too far with this system. The judicious use of a front-end flywheel has two good effects, (*a*) it slows down the vibration so it is less audible and (*b*) if we lighten the rear flywheel we, in a way, take some of the "kick" out of the shaft by letting both ends weave a little.

QUESTION:—What is the value of front-end vibration dampers, and what effect does the front-end damper have, as shown by your indicator-cards?

MR. SUMMERS:—I assume the Lanchester slipping-flywheel type is referred to here. That tends to do two things, (*a*) it pulls the period down and (*b*) it reduces the amplitude. When properly adjusted it is very effective. It cannot eliminate vibration entirely because its functioning depends upon slippage and slippage occurs only when the forces generate sufficient vibration. It takes the edge off the periods, so an engine that would be rough without a damper is commercially smooth with it.

QUESTION:—Where would be the ideal position of the flywheel to reduce torsional vibration?

MR. SUMMERS:—I do not know that I can answer that question; perhaps some might say in the center, but we cannot locate the flywheel there because the vibration that is left free at the rear end of the shaft goes back through the transmission and does more damage there. I do not know that we can improve much on the present arrangement for all-round utility.

QUESTION:—Is any practical commercial method or device available for bringing an engine into perfect balance? Is it the crankshaft alone that must be balanced or are the connecting-rods and the pistons taken into account?

MR. SUMMERS:—Engines that are not inherently out of balance may be put into perfect practical balance by dynamically balancing all rotating parts and making all corresponding reciprocating parts of equal weight. An engine so balanced may, however, have torsional vibration of the crankshaft, since this results from elasticity rather than from balance.

QUESTION:—What effects are noted when the number of main bearings is increased from four to seven?

MR. SUMMERS:—Granting that the shaft is of the same diameter, the period will occur at lower speed and the shaft may have a greater amplitude of vibration, because the shaft will have a longer center line and therefore be more limber torsionally. The effect on other vibration, such as vertical deflection, will of course be to reduce it. I would not say that any improvement, so far as torsional vibration is concerned, would be noticed, and in some cases the period of vibration is brought down so that it is more objectionable. I do not mean that you cannot build a good engine with seven bearings, but just to make that one change between two shafts that are otherwise similar will not make a great difference. I believe that a good shaft can be made with anywhere from two to seven bearings in a six-cylinder engine.

QUESTION:—What effect has reduction of crankshaft vibration on the wear of reciprocating parts?

MR. SUMMERS:—The principal objection to torsional vibration is the unpleasant noise, although it does put an additional strain on all engine parts. If gears are used it is possible to find definite spots on the gears where teeth have been hammered so they are visibly worn more than others because of the torsional vibration period. We have proved that the noise arising from torsional vibration is not, as we used to think, caused solely by the front-end gear or chain. The camshaft may be driven by an entirely separate means, as from a gear on the dynamometer shaft, and still the characteristic buzz develops when the engine goes through the periods, showing that the entire engine, reacting on the piston inertia, is set in vibration. That kind of a force certainly is not good for the bearings, and the fact that noise is heard indicates that metal-to-metal contact is being made at some of those places.

QUESTION:—Is perfect balance possible in a six-cylinder engine within the ordinary speed range?

MR. SUMMERS:—Theoretically, a six-cylinder engine is not in absolute balance but the magnitude of unbalanced forces is too small to have any practical significance. Vibration of six-cylinder engines may be regarded as due entirely to either improved balancing of the parts or deflection and harmonic reaction under torsional and centrifugal forces.

QUESTION:—Considering vibration, does any advantage accrue by fastening the engine either rigidly or flexibly at the front end?

MR. SUMMERS:—In the case of the four-cylinder engine Mr. Freeman[57], a year or so ago, told of remedying chassis vibration by placing the mounting of the engine at the rear close to the center of impact and then spring-mounting the front. We have tested one of his cars at the laboratory and I think it bears out his claim that the effect of vibration is greatly reduced. It is not pretended that the vibration of the engine is eliminated but it is isolated from the chassis.

QUESTION:—What can be done to overcome the vibration periods?

MR. SUMMERS:—A number of remedies have been applied; we try to go above the period by making a shaft light and rigid and we try to go below it by adding heavy counterweights and front-end flywheels so the vibrations will be so slow as not to be very annoying. Anything that reduces the variation in the turning effort is beneficial. Something can be gained by changing the firing order in certain engines in which the gas pressure rather than the piston inertia is the main factor in exciting vibration. Extra-heavy crankshafts are being used with good success. Friction dampers, non-metallic gears and front-end chains reduce the vibration and render it less audible.

QUESTION:—To what extent does centrifugal bending-stress distort crankshafts and throw them out of balance?

MR. SUMMERS:—In my opinion, the actual out-of-balance created by the shaft running some 0.030 in. out of line at the center with respect to the ends, I think very few exceed that at ordinary speeds, does not have an important bearing on the actual balance of the shaft. The damage comes from having a high centrifugal force imposed on the bearing and that this rotating force tends to cause a pound in the bearing, if any looseness is present. If the bearing is ample and the crankcase is stiff, very little damage is done.

QUESTION:—How much effect has the out-of-balance condition of the camshaft, or its uneven torque, on the total vibration of the engine?

MR. SUMMERS:—When we put an indicator on the camshaft, as we have done in many cases, we find that the camshaft follows the crankshaft in its vibrations, the crankshaft having much more force. A chain-driven camshaft, when the chain is loose, is affected by the lift

[57] See THE JOURNAL, April, 1924, p. 444.

of the cams, so it will trace a hexagon card through a considerable range of speed. I do not think the variations in the turning effort of the camshaft are an important factor in exciting periods compared with the crankshaft. If it is free to follow them, it will follow its own tendency, but if it is geared to the crankshaft it will respond exactly to the crankshaft vibrations.

QUESTION:—Would heat-treating to increase hardness affect torsional vibration in any way?

MR. SUMMERS:—I do not think it would, because the hardness, so far as I know, does not noticeably affect the stiffness of the shaft within its elastic-limit.

QUESTION:—In applying artificial vibration to increase the crankshaft vibration, did you notice a lessening or an increase of noise, or was the difference too small to notice?

MR. SUMMERS:—The noise was in direct proportion to the vibration; when the diagram became smooth the noise disappeared.

QUESTION:—In engines of similar design, both four and six cylinders, was the difference in vibrational forces due to acceleration or variations of pistons, and how are the impulses combined?

MR. SUMMERS:—As I am not a mathematician, I believe I had better not go into that subject. At least two points of distinction can be made between the four and the six-cylinder engine. As the former has only four cylinders, it has two impulses per revolution and for the four-cylinder engine to run into the same harmonic as the six at a given speed, the four would have to be running at 1½ times that speed. On the other hand, the four being short, has naturally a higher period than the six, if it is similarly constructed, and for that reason, in any reasonably stiff four-throw shaft, the fundamentals are much above the driving range, approximately twice as high as would occur in a similar six.

Another element enters into the four, as shown by the instrument that Mr. Hunt devised. It was demonstrated by clamping the flange of a four-throw shaft to a bedplate so the shaft projected horizontally and hanging the pistons on with the shaft throws in horizontal positions so that all the piston inertia would have to dance with the torsion of the shaft. The rate of vibration of the shaft, with the pistons in that position, was determined. Then the throws were placed vertically and the vibration rate determined again. The rates of vibration were found to vary considerably, being much slower when the shaft was in the horizontal position and the entire piston and piston-rod inertia was imposed on the shaft. So the four has an inherent dampening effect because it has a certain frequency in one position and a different one in another position which tend partially to damp out each other.

The piston-inertia torque does not vary very much in the four and the six, that is, the curves are somewhat the same in magnitude. The two extra cylinders just about compensate for the fact that the phase relations differ in the six and four.

H. L. HORNING[38]:—Mr. Crane and Mr. Newcomb once suggested to me that a crankcase for a six-cylinder engine should be stiff horizontally in the line of the crankshaft as well as vertically. In checking their suggestion I have come to the conclusion that engineers generally have entirely neglected the horizontal weakness of a crankcase and blamed our troubles largely on the crankshaft. Mr. Summers' demonstration has shown the difference in dynamic and static deflections in which the deflections increase rapidly with the speed, perhaps as V^2. Last year I had an experience along that line which made me absolutely certain that a crankcase that was stiff horizontally as well as vertically was responsible for a very smooth-running engine.

We have believed that if the regular timing-gears could be run on two shafts held in their relative positions and whose axes did not wabble or deflect, they would run almost indefinitely under the conditions of fair lubrication, but the jamming that timing-gears get with weak crankshafts and camshafts is terrific. No man who has had experience can overlook the fact that the crankshaft primarily and the dirt in the oil secondarily cause rapid gear-wear. If the front end of a crankshaft can be made to behave, the life of the gears will be increased indefinitely. Many people blame the composition of the gears and the shape of the teeth, whereas it is the shifting of the line of contact that causes the noise and the wear.

Another point which I would emphasize in connection with Mr. Summers' paper is that, while we are dealing with crankshaft vibration, we must be as interested in what happens outside of the shaft and its bearings as we are in the vibration of the shaft itself. Last year I was interested in applying to a taxicab a very small engine that I was anxious should behave well in the matter of vibration, but in making trial runs with the cab I was appalled by the terrific vibration throughout the chassis and all my fond expectations for a taxicab engine were dissipated by the vibration of this cab. By mere accident, however, I put my foot against the pedal and the whole chassis stopped vibrating. The fact is that the engine and the transmission were a unit powerplant and the brake pedal had a transverse natural vibration period within the useful engine-speeds. We changed the whole nature of the running of that chassis by correcting the pedal side-vibration. I therefore suggest that pedals be designed with the I-beam the other way. If the lever is strong enough to be outside the useful engine-speeds it will be strong enough to stand the push of any driver.

Another cause of synchronous vibration is the radiator rod that extends forward from the dash to the radiator. Vibrations are regenerative; after they once begin they are taken up by the chassis, and the chassis members with corresponding periods respond and feed them back into the part that started the vibration and so they go back and forth, making a very disagreeable riding chassis. *The best way you can ride in such a car is to get out and walk.*

If we are to benefit by these researches, we have considerable designing to do on the chassis. It is ridiculous to put in a radiator rod that multiplies vibrations and feeds them back into the mechanism, and it is atrocious to have foot levers that tell the story of what a hard time the engine is having. As an engine builder and a man who tries to get everything in balance, I plead with designers to make chassis details without natural periods inside the useful engine-speeds.

H. M. JACKLIN[39]:—The matter of torsional vibration comes down to the fact that we have a rather heavy rotating mass represented by the flywheel and attached to that a rather flexible member of a certain length in a four-cylinder engine and 1½ times that length in a six and twice that length in the eight. The whole thing appeals to me as a question of distributing that flywheel weight along the whole length of the crankshaft to reduce torsional vibration, and I think we are getting to

[38] M.S.A.E.—President, Waukesha Motor Co., Waukesha, Wis.

[39] M.S.A.E.—Assistant professor of automotive engineering, Ohio State University, Columbus, Ohio.

that very fast. Mr. Crane mentioned the fact that crankshafts were increased in size about 12 years ago. Now we are using heavier and heavier cranks.

D. G. Roos[60]:—Considerable time was spent by our company on the question of torsional vibration years ago. One of the things we tried to do was to distribute the counterweight or flywheel effect along the crankshaft, but invariably the shaft had a torsional vibration period that even the Lanchester damper, with a very large inertia-element and high frictional setting, was unable to damp out. At one time we had to design some cars for General Pershing and, to get the main bearings to stand up under continued hard service, we counterweighted the seven-bearing crankshaft and distributed the flywheel effect along the crankshaft. We used as large a Lanchester damper as we could get into the engine. Then we ran the engine at the speed where the critical period should be, and discovered that a period of some magnitude was present, for we stripped the timing-gear teeth after 7-hr. running. I made another experiment when I was with the Pierce-Arrow Company. We built some seven-bearing shafts, making the cheeks in disc form which, of course, gave them great stiffness in the plane of the discs. That engine was exceedingly rough and the periods were lowered so that the one upper period, which did not appear in the conventional form of crankshaft, came in at the lower range and the lower periods were brought down and made more violent.

Our experience has been that the effect of adding any inertia along the shaft or putting a flywheel in front, not only lowers the period but greatly increases the amplitude and apparently the amount of stored-up energy in the shaft. The effect, we found, was extremely destructive of chains and front-end gears. At present our solution is to use a seven-bearing crankshaft with very stiff cheeks. In making static deflections of the crankshaft in its bearings in the crankcase, we found that by far the greater amount of deflection occurs in the torsional twisting of the cheeks. There is only about 5 per cent in the main bearings and about 18 or 20 per cent in the pins; the rest occurs in the twisting of the cheeks. Much can be done to reduce the torsion, in a seven-bearing shaft at least, by making the cheeks very stiff and thickening them in the direction of the axis of the shaft.

Our solution has been to make the shaft as stiff as we could, use a Lanchester damper with sufficient diameter but enough inertia effect to take care of the lowest period, and then take care of the residual vibration that is always left in the shaft by a cushioning spring gear. That method has been used effectively in producing a very smooth engine having a train of five gears at the front end. It is also used successfully, I think, in the Pierce-Arrow and the Rolls-Royce.

Mr. Summers:—Our experience checks exactly with what Mr. Roos has said. Any time we want to build-up a beautiful period we put on either a flywheel in front or counterweights or something like that. That has a tendency to accentuate the period in a very definite critical speed. Sometimes the period will extend over perhaps less than 100 revolutions but it builds-up very sharply. With the right proportion between the rear and the front-end flywheels it does become less so far as being a disturbing element is concerned, at least as measured at the front end; I have not measured at both ends to see exactly where the energy goes. The amplitude is usually greater but if we slow the frequency down enough the noise is sometimes less.

Mr. Jacklin:—Were these weights added without reducing the normal flywheel? My idea is to eliminate the flywheel entirely, that is, a torsionally rigid member, and distribute the weight along the crankshaft. I do not believe that has been done yet, but we are getting close to it with the heavy cranks and very light flywheels. One of the latest cars announced comes very close to that ideal.

R. H. Weinert[61]:—Mr. Roos spoke about the Pierce-Arrow crankshaft, made with solid cheeks, being a very rough crankshaft, then later he said that most of the torsional vibration was in the cheek. As the statements do not seem to correspond, perhaps he will explain them more fully.

Mr. Roos:—We did not add much to the stiffness of the cheek under torsional deflection about an axis radial to the main axis of the shaft but made it very stiff against bending as a cantilever along that same axis. When you consider the pin as being on a flat plate, the plate did not have great resistance against twisting.

Chairman Crane:—It is a very discouraging thing in laying out a six-cylinder shaft to get real torsion in these cheeks because of the way the torsion figures out; more length has to be taken. Mr. Roos means that if you make a cylindrical cheek of large diameter but thin fore and aft, much weight is added without gaining much resistance to torsion, while, if you put the same amount of metal in a cheek longitudinally, the torsional resistance will rise rapidly in proportion to the flywheel effect.

Mr. Weinert:—What effect on bearing wear has the extra weight in a crankshaft? As Mr. Crane just said, there is a lot of weight in a crankshaft that need not be there. The centrifugal force of that weight would tend to bend the crankshaft and wear the bearings. In some cars that has been very pronounced and has actually been known to increase the friction horsepower of an engine.

T. J. Litle, Jr.[62]:—I notice the tendency to make crankshafts of very large diameter but do not see why that need be carried all the way to the front end. Why do we not make the tapered shafts we heard so much about some time ago?

Prof. E. P. Warner[63]:—It seems to me that the distribution of the flywheel weight along the crankshaft is fundamentally wrong. If we had a weightless crankshaft that possessed finite stiffness, it would theoretically have a zero period, as no force would be required to accelerate it. Conversely, any force would suffice for an infinite acceleration, and the transfer of twisting moment from one point along the shaft to another would involve no loss of time and no change in the velocity of the flywheel. That is the condition that we ought to approximate, and the closer we come to it, that is, the more weight we have in the flywheel and the less we have in the crankshaft at any point along the shaft, assuming of course a given stiffness in the crankshaft, the better off we are likely to be.

Chairman Crane:—The more optimistic among the engineers can live in hope that someone will double the modulus of elasticity of steel. That would be a great help. What we probably will do is to pick out the shaft for the job. The aviation designer has no crankshaft problem; he puts bearings all the way along the shaft and operates the engine at a speed that is not in a period, which he can do because the critical period is

[60] M.S.A.E.—Vice-President in charge of engineering, Locomobile Co. of America, Bridgeport, Conn.

[61] M.S.A.E.—Efficiency engineer, Studebaker Corporation of America, Detroit.

[62] M.S.A.E.—Chief engineer, Ford Motor Co., Dearborn, Mich.

[63] M.S.A.E.—Professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

largely at full-load operation, at least in its worst manifestation. It is surprising what very large shafts can be run successfully under those conditions in a rigid crankcase at very high speeds. Shafts more than 3 in. in diameter in an engine of 600 hp. run at 2300 r.p.m. under full load for a long period of time with practically no serious bearing wear.

The motor-car problem is much harder and what has to be determined is what car-speed, combined with smoothness of operation, will satisfy the public. The designer, having decided what he will give the public, will have to pick his engine size and his crankshaft accordingly. Without question smoothest operation at certain high car-speeds can be obtained with a larger engine turning slower; that is, you can put the period beyond the driver's range just as well by running the engine slower as you can by increasing the size of the crankshaft.

We are going through a period today of running up the engine-speed to obtain the desired result, which certainly has been a big improvement. I do not think anyone would think of going back to the old gear-ratios of $2\frac{1}{2}$, $2\frac{3}{4}$ or 3 to 1 that were common in 1905 and 1906, or even some of the reckless ratios of $3\frac{1}{2}$ to 1 that occurred some years after that. On the other hand, we are now encountering difficulties in obtaining smooth running at high speed, not only because of crankshaft vibration but vibration of other parts of the automobile, such as the propeller-shaft, the flywheel and the clutch. Take a faulty plate clutch, for instance, that has been reconditioned at a service-station; every probability exists that the plates are not in running balance after they have been replaced, for the service-station has no way to determine that. So we get into a series of vibrations that can be obviated only by not running the engine so rapidly.

We have good engines today I believe, with various numbers of bearings. I think we have three-bearing sixes, four-bearing sixes and seven-bearing sixes that are all good. For very high-speed operation I would personally pick a seven-bearing shaft with very large-diameter main bearings, very rigid cheeks and rather small-diameter crank-pins. For a rather slow-speed engine of very moderate cost, cheap to service and simple, I would pick the three-bearing shaft. Then we have all the intermediate types, the four-bearing plain shaft or the four-bearing counterbalanced shaft. All have their places; the public eventually will decide among them.

OTTO M. BURKHARDT[64]:—I feel that the flywheel has been put in jeopardy; things have been blamed on it for which it is not responsible. The flywheel has nothing to do with the torsional vibrations; they come from impulses. The flywheel acts as a resonance for the impulses, which travel along the crankshaft to the flywheel, where resonance is formed. If a flywheel is put on the front end, the resonance is not so bad, although the vibrations are still there, hence the front-end flywheel will do some good under certain circumstances.

As Mr. Roos mentioned, we tried a crankshaft with discs in the Pierce-Arrow car but it did not help because we did not strengthen the discs and did not make much change in the flywheel. Hence the resonance was the same because, no matter what masses were distributed along the shaft, the impulses remained the same. Consequently, the vibrations were the same; and so long as the resonance is there they will occur.

Coming back to what really causes vibrations, there are impulses first, then a yield. Tests show that relatively little yield takes place in the main bearings, which contribute approximately only 25 to 30 per cent to the total deflection of the crankshaft. The rest is in the crankpins and in the crank cheeks. With seven main bearings the crankpins are essentially cantilevers; they are not subject to torsion, but are subject merely to a force. Hence they do not contribute to torsional vibrations.

In three-bearing and four-bearing crankshafts the crankpins are subject to torque, and from this point of view such shafts in a six-cylinder engine always will vibrate more torsionally than the other crankshaft, to say nothing about transverse vibrations, which are very much worse, inasmuch as the transverse deflections increase as the cube of the distance between bearings. If the distance be three times as much in the case of a three-bearing shaft, the transverse deflection will be 27 times as much. We cannot get rid of this.

I repeat, in a seven-bearing shaft we have torsional vibration originating only in the main bearings, and out of this we can nicely balance it with frictional vibration.

CHAIRMAN CRANE:—At other places in a motor-car vibration forces itself upon us without being invited. One of these is in the camshaft. In the case of a very free-running camshaft of rather small diameter used in an overhead-camshaft engine with a vertical-shaft drive to the camshaft, the free-running being due to small bearings, good lubrication and large rollers on the rocker-arms, a sufficient torsional period was developed in the camshaft to stretch the driving chains badly. By increasing the diameter of the camshaft and applying friction between the camshaft and the drive, the life of the driving chains was increased about four times, showing that the diagnosis was correct.

In this Country nearly 500 automobiles are running with a Lanchester damper carefully hidden inside the transmission. I do not think the owners have ever known it was there, but it was very necessary to absorb a bad torsional period in the drive between the engine and the rear axle. That period was excessive when coasting with the engine running at 50 m.p.h. It was most unpleasant in the car and could not be hidden in any way. Another period at about 30 m.p.h. was more of the order of a steady growl. It was blamed on bad transmission-gears for some time before the real cause was discovered.

A fine mechanical development is waiting for an ingenious designer, and that is to make a good commercial engine with the camshaft drive at the rear end. I can say, from having built engines with gear drive and chain drive at the rear, that the life of the drive is phenomenal, it is practically unlimited. The difference between the life of a chain or gear at the rear end of an engine against the best combination we can get at the front end would be highly satisfactory if we could realize it in a good commercial design; that is, something that could be built readily and simply, and that could be serviced properly afterward.

[64] M.S.A.E.—Consulting engineer, Pierce-Arrow Motor Car Co., Buffalo.

FREDERICK HOLLIS WELLS

WHILE testing a racing car called Wells' Hornet, which he had designed and built to enter in this year's Memorial Day race at Indianapolis, Frederick Hollis Wells was killed instantly on the Motor Parkway, Long Island, on April 22 last, between Central Islip and Brentwood, N. Y. He is reported to have been traveling at a speed of 80 m.p.h. when the car struck two trees, throwing Mr. Wells, who was alone in the car, out and breaking his neck. The machine had been towed to the parkway by Kenneth Brostman, a mechanic, and two trial runs had been made before the accident.

Mr. Wells, who had been a Junior Member of the Society since March 11, 1920, was the son of Major Arthur Wells, of Newark, N. J. He was born on Aug. 10, 1898, and was a graduate of the class of 1921 in mechanical engineering at Stevens Institute of Technology, Hoboken. While studying at the Institute, he designed and constructed in its shops a high-efficiency racing engine and after graduating was engaged in developing and testing a rotary-valve engine with the intention of organizing a company for the construction of automobiles. He competed in the 500-mile Memorial Day race at Indianapolis for each of the last 3 years.

WALTER W. CARPENTER

HEART disease caused the sudden death of Walter W. Carpenter, of Detroit, on April 13, last. He had been associated with Harry H. Knepper, of Detroit, manufacturers' agent, since 1919 and was well known in the automobile trade, especially among the engineers and purchasing agents of plants building automobile bodies.

Mr. Carpenter was born in Chicago on June 26, 1885, and entered the automobile industry in 1912 as sales engineer with the Warner Instrument Co. and served successively in a similar capacity with the Jones Speedometer Co. and its successor, the H. W. Johns-Manville Co.; the Pumpelly Battery Co. and its successor, the Prest-O-Lite Co.; the Detroit Battery Co. and with Harry H. Knepper. He was elected to Associate Member grade in the Society on March 15, 1921.

JOHN McGRATH

NOTIFICATION of the death of John McGrath, vice-president of the Eberhard Mfg. Co., Cleveland, on April 16, last, has been received. He had been an Associate Member of the Society since Sept. 15, 1921. Mr. McGrath was born at Philadelphia on June 9, 1861. He had been connected with the Eberhard Company since 1888, being actively engaged in designing and superintending the construction and sale of wagon and automobile irons. At the time of his election to membership in the Society he was assistant treasurer of the Company and later became its vice-president.

STANDARDIZATION

MANY and serious obstacles stand in the way of the development of international industrial standardization, such as differences in language, racial temperament, historical and industrial background, limitations imposed by geographical conditions, the metric and English systems of weights and measures, national animosities and rivalries, exigencies of commercial conditions, ignorance on the part of industrial leaders of the significance or even of the existence of foreign work and the instinctive conservatism, not to say suspicion, of a large proportion of men toward new developments and ideas.

On the other hand, important considerations and powerful forces tend toward international standardization, such as the scientific basis that has been laid in the extensive system of physical and chemical units and measurements, much as an alphabet forms a basis for written language; the growth of international trade; the increasing use of specifications and other industrial standards in foreign commerce; the increasing interdependence of national industries upon each other; the increasing general interest in and knowledge of international affairs; the greater tendency to study foreign industrial developments and to adopt those which are applicable to home industries; the circumstance that specific industries are developing more and more along the same lines in different countries; and the fact that industrial leaders are taking a larger and larger perspective in planning for the future.

STANDARDIZATION NEAR

The actual line of development must necessarily be the resultant of such conflicting tendencies and forces. In my opinion, a very considerable amount of international standardization will take place in the next few decades. This opinion is based largely upon evolutionary considerations. For example, it seems to me that the problems now confronting each of the national standardization movements are much the same as those that surrounded the movement toward trade associations in this country a few years ago, while international standardization will follow in much the same way but without going so far or so rapidly.

Whatever the ultimate outcome may be, and whatever one's estimate of the success of the movement toward international standardization may be, it seems to me the next step is in any case the same, to develop as full and as free an interchange of information as conditions will permit. Through some such procedure can standardization best be firmly established.—Secretary Agnew, American Engineering Standards Committee.

OUR SHARE OF INTERNATIONAL TRADE

THE National City Bank of New York's trade record figures of world international trade, which extend from 1800 down to and including 1924, show that our own share of world international trade has advanced from about 8.0 per cent in 1800 to 10.5 per cent in 1913, 14.0 per cent in 1918, the closing year of the war, and approximately 14.0 per cent in the year that ended Dec. 31, 1924.—*Economic World.*

PUMPING DEEP OIL-WELLS IN CALIFORNIA

ALL calculations referring to the possible production of an oil sand are so uncertain that no conclusion can be drawn as to how much oil is available for each individual pumping well. All tests and experiments on pumping wells are purely comparative and the best pumping equipment is the one that will produce the largest amount of oil at the smallest lifting expense.

No extensive changes have been made in the construction of pumping equipment. When oil was discovered and the necessity to pump it out of the well appeared, it was logical to use the same type of pump that had been successfully applied to the pumping of water wells. This equipment consists of a string of tubing, a working barrel placed at the bottom of the well holding a hollow plunger which is moved by rods or cables in a reciprocating motion inside of this barrel. An inlet-valve, the standing valve, at the lower end of the barrel and an outlet valve, the traveling valve, fastened at the top or at the bottom of the hollow plunger are the main features of the construction. Every up-stroke of the plunger creates a vacuum between the two valves, causing a flow of liquid from the outside into the barrel, and every down-stroke of the plunger creates a pressure between the two valves, causing the liquid to flow through the traveling valve into the string of tubing. This simple pumping machinery has been in use ever since and, while the pumping wells steadily increased in depth, the same type of plunger seemed to satisfy pumping conditions.

When the deep wells in several oil fields of the Los Angeles basin, particularly at Santa Fe Springs, ceased flowing, and were put on the pump, it was found that the ordinary pumping installations were not sufficient to lift the oil, the wells in many cases refusing to yield any oil whatsoever. Three possible methods can be employed for producing oil from a non-flowing well; (*a*) by mechanical means, the pumping machinery being in the derrick and the power being transmitted by mechanical connections, such as rods, cables and the like, to the pump submerged in the fluid; (*b*) by compressed air or gas raising the fluid to the surface by aerated columns moved by the velocity of compressed and outflowing gases or air; and (*c*) by other means, such as hydraulic and electric power transmission. The third method may be discarded immediately, as no proved constructions are known which would adapt themselves for the purpose. The second method may be discarded temporarily as it has not a general adaptation to pumping wells, nor has it any immediate possibility of a practical and efficient solution.

The pumping of sandy wells has always been a great problem, in fact sandy wells with the presence of water have often given so much pumping trouble that many of them are temporarily abandoned. The action of free gas in pumping wells has been the subject of extensive studies, for it seems to be incomprehensible why gas, which is the most valuable source of energy for a flowing well, should be detrimental to the production of the same well when put on the pump. The experience obtained in the deep wells of the Los Angeles Basin with improvements in pumping equipment gives hope that the pumping of deep wells around the 5000-ft. mark will soon become a matter of routine.—From an address delivered at the American Petroleum Institute Meeting by J. A. Zublin, of the General Petroleum Corporation.

EXPLANATION OF NATURAL PHENOMENA

LESS is understood of natural phenomena than is commonly believed. The attempt to reduce all phenomena to matter in motion has signally failed; and the scientific investigator accordingly retains unimpaired that capacity for wonder which Dr. Russell attributes to the ancient Greeks. As matters stand we have to be content to push particular theories merely as far as they will go, and probably the hope of ultimate explanations of natural phenomena has been definitely abandoned by most physicists.

The great generalizations of the nineteenth century are now recognized as insecurely based. The conservation of mass, a doctrine that led to such magnificent results in the past, has had to be abandoned, and the fact that Mercury fails to keep time is now seen to be a consequence of the variation of its mass with its velocity of movement. Presumably the anomalies detected in the motion of the moon may have a similar source. Whether the doctrines of the conservation of energy and the conservation of momentum are any more firmly based than that of the conservation of mass still remains to be seen. In any case, a proof can only extend to the limits of observation, beyond which we cannot extrapolate without serious risk of error. In this connection it may perhaps be noted that it is now generally recognized that the second law of thermodynamics has no universal validity. As Tait pointed out years ago, Clausius' statement of this law must be violated in every mass of gas. Much attention has of late years been devoted to the study of these fluctuations in the constitution of a gas, and the possibility of a cubic foot of air separating itself spontaneously into its component gases, is recognized, though calculation shows that such an event could only occur once in trillions of years. Maxwell and Kelvin were, of course, much more cautious than Clausius in their formulation of this second law of thermodynamics and expressly excluded from its range, cases in which an intelligence might be able to seize on and sort out individual molecules.

Other difficulties in the understanding of nature were made evident by the experiments that led to Planck's atomization of energy, a concept that it is extremely difficult to picture but that has led to very great advances in many departments of physics, and that must assuredly involve some substantial truth that will remain valid, even should very considerable modifications in detail ultimately prove necessary.—*Engineering* (London).

USE OF ELECTRICITY IN ITALY

THE extent to which electricity is being used in Italy shows a surprising development, and indicates that Italy is becoming more and more independent of imports of coal because of her ability to utilize her waterpowers to produce electric current. In 1898 the electric current used in Italy amounted to only 180,000 kw-hr.; in 1908, to 1,000,000,000 kw-hr.; in 1915, to 2,300,000,000 kw-hr.; and in 1924, to 5,500,000,000 kw-hr.—*Economic World.*

TRAFFIC-TRANSPORTATION PLANNING

THE majority of our people now live in the cities and towns, and the curve is rising, while that of rural population is flattening out perceptibly. This drift to the cities is most significant; also the fact that cities of the 1,000,000 class showed in the last decade a distinct recession in growth rate, while the near-great cities of the 500,000 class are growing with marked rapidity.

Population density is an important index. In 32 metropolitan centers having populations of over 200,000 it increased 25 per cent in the last decade to an average of 13.9 per acre, or 8860 per sq. mile. Compare this with Chicago's *maximum* of 160,000 and New York City's Ghetto with 640,000 per sq. mile, as against an *average* of 14,000 and 18,800 per sq. mile respectively. Thus the maximum-average ratio of New York City is just three times that of Chicago. It is these high spots that zoning and transportation must correct.

Suburban population is growing faster than in the city proper in these 32 large cities; but it is just the reverse in the 30 cities of the 100,000 class. This is clearly the effect of congestion, for the city areas of the 32 larger cities are one-fourth of the total metropolitan areas; in the smaller, 1/20. Here is involved a total of 26,000 sq. miles for future development, about the same as in the States of Maine, West Virginia or South Carolina and 27 times Rhode Island. This is a measure of our future problem of transportation planning.

The United States now has as many motor vehicles as telephones; in California, as many as there are families. If the California density shall be reached over the United States, then clearly 30,000,000 motor vehicles are in sight around 1940. About 73 per cent of all passenger automobiles in the United States are in cities and towns of over 1000 people, 9,500,000 or more, averaging only 1.60 families per motor car as against 1.93 in 1922. This registration has increased 27 per cent since 1922.

The complete transportation plant of the Country—rail, water, road, trolley—has cost in excess of $50,000,000,000 and $15,000,000,000 per year to operate. About two-fifths of this is due to motor transport. Transit traffic increases nearly as the square of the population increases; railroad tonnage nearly as the cube; railroad passengers faster; and passenger mileage and ton mileage around the fourth power of the population. Motor-vehicle traffic in New York City is said to grow somewhat less than the registration. In general, it may be said that, when population doubles, traffic as a whole increases eight times. That is, by 1940, facilities should be from three to four times as great as those of today. At least we should plan ahead for doubling our present city operations. Anything less is suicidal. This means all forms of traffic and transportation, rail, road, water and, not to be forgotten, air.

Capacity of traffic throats and terminals is the key to the problem, for all traffic largely focuses there. Capacity is the product of size of unit and average frequency of movement, and speed comes only with relief from obstructions and delays. The most important need of our cities is street, track and terminal expansion, and seldom has the problem been attacked as a whole. Chicago still has only 2 elevated tracks in the "loop" to serve 13 feeders. New York City's railroad service handles one-fifth of the entire rail-passenger traffic of the United States, or one-fourth of the remainder. The suburban traffic is largely rapid transit, rather than standard steam service suited to monumental terminals. In consequence, city streets have to take it all.

Higher efficiency standards seem to be the only quick way out. In a recent survey, I found the "loop" street outlets being used to only 25 per cent of their possible capacity, and assuming solid parking at that. Capacity could be doubled, yet the city is congested. New York City is passing 2800 motor vehicles *per traffic lane per hour.*

Billions can be saved to the future cities by planning on broader and more fundamental lines. Already, there are reported to be 80,000 miles of city paved streets, costing somewhere between $3,000,000,000 and $4,000,000,000, or from $40,000,000 to $50,000,000 per 1,000,000 of city population. It is unthinkable to attempt *doubling* their capacity on the *present* uneconomic methods of use. Arcading, elevated walkways and street-grade separations have yet to be worked out on some equitable plan of cost distribution. And motorbus transit will only accentuate the difficulty.

A traffic transportation plan for the future cannot be postponed except by vast distortion of city growth. It demands co-ordinated effort of all transport and industrial agencies, in proportion as they contribute to, or are affected by, traffic, rail, trolley, road, water and air. It needs leadership. Cities will never be able to cope with the problem by abortive legislation or drifting. It must be attacked scientifically and in a large way!

Our cities have grown around transportation. While traffic increases by *multiplication*, physical facilities have only grown by *addition*, if at all. The only logical end of this unbalanced race is the increased economic burden of living and doing business. It is strange that, with such colossal economic losses even now being experienced, cities should be so hesitant to undertake the microscopical expense of a thorough technical survey of their problems and planning for a future that is bound to come.—J. Rowland Bibbins in *Annals of American Academy.*

THE COUNTRY'S DOMESTIC AND INTERNATIONAL TRADE

SECRETARY HOOVER has brought out the fact that, when the values of our imports and exports in March, 1924, are recomputed in terms of the prices obtaining in the years immediately preceding the European War, it is found that from a quantity or volume standpoint our foreign trade in March this year was approximately 50 per cent greater than our foreign trade in March, 1914. The intake of commodities during March was largely in the form of raw materials, while the principal place among the month's exports was held by the products of manufacture.

The most dependable indicia of general production and distribution all support the conclusion that American industry as a whole was never more active than it is at the present time and that the consumption of the products of industry was never greater. The movement of all the most widely accepted indexes of industrial production and industrial activity in the past half-year or so has been susceptible of no other interpretation than that our manufacturing industries in general are busier than they ever before were.—A. R. Marsh in *Economic World.*

Applicants *for* Membership

The applications for membership received between April 15 and May 15, 1925, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALBINSON, H. H., designer, engine division, General Motors Truck Co., *Detroit*.

AUSTIN, ERNEST C., president and general manager, Austin-Road-Governor Co., *Poughkeepsie, N. Y.*

BAILEY, GEORGE M., branch manager, Mack-International Motor Truck Corporation, *Indianapolis*.

BAKER, M. P., engineer, General Motors Research Corporation, *Dayton, Ohio*.

BARNES, SWIFT C., sales manager, Walden-Worcester, Inc., *Worcester, Mass.*

BARNES, THOMAS LAWSON, manager of sales, B. F. Goodrich Rubber Co., *Akron, Ohio*.

BERNARD, ERVING H., sales engineer, Premier Motors, Inc., *New York City*.

BESSE, CAPT. EDWARD H., Quartermaster Corps Intermediate Depot, Camp Normoyle, *San Antonio, Tex.*

BLACKER, HARRY E., service-manager, Nash-Buffalo Corporation, *Buffalo*.

BLANCHARD, HAROLD F., technical editor of *Motor*, International Magazine Co., *New York City*.

BOHNER, CLYDE C., assistant to president, Tung-Sol Lamp Works, *Newark, N. J.*

BOOTH, FRED C., engineer, Bijur Lubricating Corporation, *New York City*.

BROWN, CLIFFORD E., service superintendent, Mack-International Truck Corporation, *Los Angeles*.

BURKE, JOSEPH EDWARD, purchasing agent, Dodge Bros. of Canada, Ltd., *Toronto, Ont., Canada*.

BURKHARDT, HARRY L., director of engineering, Ruckstell Sales & Mfg. Co., *New York City*.

CHAMBERLIN, G. W., sales engineer, Fruehauf Trailer Co., *Detroit*.

CHASE, HAROLD E., student, college of applied science, Syracuse University, *Syracuse, N. Y.*

CLARK, WILLIAM M., superintendent of motor equipment, S. S. Pierce Co., *Boston*.

COTTELL, HARRY D., salesman, Laidlaw Co., Inc., *New York City*.

CRAWFORD, SIDNEY L., vice-president and treasurer, Loyal Certified Lubricants, Inc., *New York City*.

DAVIS, JAMES W., aeronautical draftsman, engineering department, Air Service Intermediate Depot, *Scott Field, Ill.*

DECKARD, HOWARD C., general superintendent, Taft-Peirce Mfg. Co., *Woonsocket, R. I.*

DEPEW, RICHARD H., JR., aviator and vice-president, Fairchild Flying Corporation, *New York City*.

DICKINSON, J. H., service-manager, American Bosch Magneto Corporation, *Chicago*.

DONNELLY, J. A., branch manager, Mack-International Motor Truck Corporation, *New York City*.

DORMAN, FRANK D., general manager, Automatic Machinery Co., *Bridgeport, Conn.*

DUESLER, GEORGE, district service supervisor, Mack-International Motor Truck Corporation, *Los Angeles*.

FAIRBANKS, WILLIAM H., supervisor of shops and vehicles, Southern California Telephone Co., *Los Angeles*.

FERGUSON, HAROLD G., engineer, Automotive Valves Co., *Los Angeles*.

FRANC, JOSEPH J., assistant service-manager, Oldsmobile Pittsburgh Co., *Pittsburgh*.

FRAZZA, J. F., service-manager, Saskatchewan Motor Co., Ltd., *Saskatoon, Sask., Canada*.

GIBBONS, WILLIAM E., tracer, Premier Motors, Inc., *Indianapolis*.

GIBBS, FRANK R., assistant general service-manager, Studebaker Corporation of America, *South Bend, Ind.*

GOODRICH, F. H., draftsman, C. G. Spring & Bumper Co., *Detroit*.

GOUNDRY, ERVIN J., salesman, Russell Mfg. Co., *Middletown, Conn.*

GUTHRIE, CAPT. PAUL R., motor transport branch, Quartermaster Corps, Camp Holabird, *Baltimore*.

HEINRICHS, ROBERT M., sales engineer, Bendix Brake Co., *Chicago*.

HERTZOG, HOWARD S., president and general manager, Hertzog-Thompson Motor Co., *Pottsville, Pa.*

HOWARD, MAJOR CLINTON W., chief engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio*.

HUNTER, FENLEY, general manager, Hunter Illuminated Car Sign Co., *Flushing, N. Y.*

JACKSON, ARTHUR C., factory manager, Miller Lock Co., *Frankford, Philadelphia*.

JOACHIM, WILLIAM F., mechanical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*

JOHNSON, ROY W., engineer, Paraflector Co., *Kenosha, Wis.*

KEARNEY, DANIEL P., mechanical engineer, Eclipse Machine Co., *Elmira, N. Y.*

KILROE, HARRY B., manufacturing engineer, Briggs & Stratton, Inc., *Milwaukee*.

KOEHLER, H. G., research chemist, Mellon Institute of Industrial Research, *Pittsburgh*.

KRALL, J. I., treasurer, Cleveland Automobile Co., *Cleveland*.

LAMBERSON, A. R., superintendent and automotive engineer, Westcott Burlingame, Inc., *Albany, N. Y.*

LIEBIG, J. M., superintendent, Altorfer Bros. Co., *Peoria, Ill.*

LINKERT, HOWARD W., engineer, Wheeler-Schebler Carburetor Co., *Indianapolis*.

LIVINGSTONE, C. J., assistant fellow, Mellon Institute of Industrial Research, *Pittsburgh*.

LODGE, ALBERT, treasurer and general superintendent, E. A. Patch Co., Inc., *Boston*.

MCMAHAN, E. V., production manager, Ajax Rubber Co., *New York City*.

MCTAVISH, RUSSELL C., service representative, Durant Motors of Canada, Ltd., *Toronto, Ont., Canada*.

MASTERS, ELMER, Muncie products division of General Motors Corporation, *Muncie, Ind.*

MILLER, HERBERT L., branch manager, Moreland Sales Corporation, *San Francisco*.

MINTER, CLARKE C., research chemist, 111 West 42nd Street, *New York City*.

MOELLER, H. O., division service-manager, Mack-International Motor Truck Corporation, *Chicago*.

MOORE, ARLINGTON, inventor and engineer, Moore Invention Corporation, *Worcester, Mass.*

MYERS, D. F., engineer, Service Motors, Inc., *Wabash, Ind.*

NEUKUMETER, LOUIS H., designer, Brooks Steam Motors, Ltd., *Stratford, Ont., Canada.*

PATTEN, H. H., carbureter superintendent, Dave P. Kingsley Co., *Los Angeles.*

PAULUS, G., factory manager, Adam Opel, *Russelsheim A/M, Germany.*

PHILLIPS, GEORGE G., senior inspector, Air Service, *Dayton, Ohio.*

PRICE, JACOB L., president and general manager, Bendix Brake Co., *Chicago.*

REINHART, HOWARD A., salesman, Shell Co. of California, *Oakland, Cal.*

REYNOLDS, GEORGE E., representative, Four Wheel Drive Auto Co., *Clintonville, Wis.*

REYNOLDS, JAMES J., representative, Ferodo & Asbestos, Inc., *New Brunswick, N. J.*

RICHARDS, C. R., chief engineer, Vacuum Oil Co., Proprietary, Ltd., *Melbourne, South Australia.*

SCHORY, CARL F., secretary of contest committee, National Aeronautic Association, *City of Washington.*

SCOTT, JOHN B., chief inspector, Yellow Sleeve Valve Engine Works, Inc., *East Moline, Ill.*

SHAW, SIDNEY B., automotive engineer, Pacific Gas & Electric Co., *San Francisco.*

SHUTTS, LEROY W., layout draftsman, General Motors Research Corporation, *Dayton, Ohio.*

SILBERMAN, JACOB A., treasurer, Chevron Motor Corporation, *Jersey City, N. J.*

SILVER, H. R., secretary, Shuler Axle Co., Inc., *Louisville, Ky.*

SMITH, HARRY B., shop foreman, Oldsmobile Pittsburgh Co., *Pittsburgh.*

SMITH, ROGER W., sales manager of bronze back and die-casting departments, Hoyt Metal Co., *St. Louis.*

SMITH, THOMAS W., experimental engineer, engineering section Quartermaster Corps, Camp Holabird, *Baltimore.*

SPILLER, WILLIAM RAYMOND, laboratory engineer, White Motor Co., *Cleveland.*

STEARNS, H. E., JR., engineer, Engine & Carburetor Co., *Baltimore.*

STOCK, E. W., regional service manager, White Co., *Cleveland.*

STONE, HARRY A., sales representative, Electric Service Supplies Co., *Philadelphia.*

TATTERSFIELD, ERNEST E., field engineer, Dave P. Kingsley Co., *Los Angeles.*

THOMAS, C. C., service engineer, Pierce-Arrow Motor Co., *Buffalo.*

TIFFANY, D. H., president, D. H. Tiffany Corporation, *Rochester, N. Y.*

WARNER, PHILLIPS, assistant general sales manager, Six Wheel Co., *Philadelphia.*

WARRINER, L. L., assistant chief engineer, Fairbanks, Morse & Co., *Beloit, Wis.*

WAUTERS, A., foreman of research department, Rickenbacker Motor Co., *Detroit.*

WELLES, HOWARD W., engineer, Commercial Truck Co., *Philadelphia.*

WENNSTROEM, ROBERT T., secretary, treasurer and general manager, Van Wheel Corporation, *Oneida, N. Y.*

WHITBECK, J. E., superintendent, Air Mail Service, *City of Washington.*

WHITTEN, ERNEST, partner, C. E. Whitten & Sons, *Lynn, Mass.*

WOODRING, PAUL M., sales engineer, Vacuum Oil Co., *Philadelphia.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between April 10 and May 11, 1925. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

ALBRIGHT, GEORGE V. (A) vice-president and service-manager, Akron Oldsmobile Co., 888 East Market Street, *Akron, Ohio.*

ALSBERGE, VICTOR L. (A) garage foreman, Brooklyn Edison Co., *Brooklyn, N. Y.*, (mail) 206 Washington Park.

BECKER, CHARLES F. (J) supervisor of engine testing laboratory, Associated Oil Co., *Associated, Cal.*

BOCKIUS, CHRIS (M) development manager, Manhattan Rubber Mfg. Co., 61 Willett Street, *Passaic, N. J.*

BUNTING BRASS & BRONZE CO., (Aff.) *Toledo.*
Representative: Thompson, George, general superintendent.

CAMPBELL, WORTHINGTON (A) lawyer, Redding, Greeley, O'Shea & Campbell, 38 Park Row, *New York City.*

CINCINNATI MILLING MACHINE CO., (Aff.) *Oakley, Cincinnati.*
Representative: Wood, Walter C., vice-president.

CREDNER, LOUIS (A) principal of Y. M. C. A. automobile school, 40 West 66th Street, *New York City.*

CURL, L. C. (A) general purchasing agent, Continental Motors Corporation, *Detroit*, (mail) Imperial Hotel.

DENISON, ERNEST B. (A) salesman, Western Electric Co., *Detroit*, (mail) 7310 Second Boulevard.

DOUGLAS, ALBERT L. (A) service manager, Mack-International Motor Truck Corporation, Philadelphia, (mail) 594 Barrett Avenue, *Bryn Mawr, Pa.*

EARNEST, STANLEY (A) instructor in Air Service, (mail) 508 West Main Street, *Belleville, Ill.*

ELY, SUMNER BOYER, (M) assistant professor of commercial engineering, Carnegie Institute of Technology, Schenley Park, *Pittsburgh*, (mail) 5122 Pembroke Place.

FALK, WILLIAM M. (M) American Motor Rod Corporation, 1800 West Lehigh Avenue, *Philadelphia.*

FERRIN, ARTHUR W. (M) engineer, Remington Oil Engine, Inc., *Keyport, N. J.*, (mail) Raritan Inn.

FLETCHER, AUSTIN B. (M) consulting highway engineer, bureau of public roads, Department of Agriculture, *City of Washington*, (mail) 511 Willard Building.

FOX, JOHN H. (M) executive engineer, Pittsburgh Plate Glass Co., 1618 Frick Building, *Pittsburgh.*

GEERTZ, ERIC (J) engineer, Skinner Automotive Device Co., 1637 Lafayette Boulevard, *Detroit.*

GRAHAM, JOHN (A) president, Holbrook Co., *Hudson, N. Y.*

HAMILTON, C. E. (A) president, Automotive Gear Works, Inc., *Richmond, Ind.*

HAREYAMA, NAOKICHI (A) president, Hareyama Auto Mfg. Co., *Tokyo, Japan*, (mail) 447 Nakashibuya.

HARPER, DONALD A. (J) commercial engineer Tung-Sol Lamp Works, 95 Eighth Avenue, *Newark, N. J.*

HAYDEN, C. J. (A) president, Hayden Automobile Co., *Stamford, Conn.*, (mail) 737 Main Street.

JACKSON, ALLAN (A) director and vice-president, Standard Oil Co. of Indiana, Room 1100, 910 South Michigan Avenue, *Chicago.*

JOSE, RUDOLPH (A) president and treasurer, Washington-Cadillac Co., *City of Washington,* (mail) 1138 Connecticut Avenue, Northwest.

JUDKINS, JOHN B. (A) president, J. B. Judkins Co., *Merrimac, Mass.,* (mail) 26 Grove Street.

KAPLAN, SAMUEL (A) executive, Monroe Furniture Co., Ltd., *Monroe, La.,* (mail) 416 Grammont Street.

KLEPS, EDWARD W. (A) service manager, Lenk Electric Co., Boston, (mail) 22 Peverell Street, *Dorchester, Mass.*

LADISH DROP FORGE CO., (Aff.) *Cudahy, Wis.*
Representative: Tisdale, N. F., metallurgist.

LAWSON, CHARLES T. (A) superintendent of transportation, San Joaquin Baking Co., *Fresno, Cal.,* (mail) 3635 Grant Avenue.

LOTT, A. L. (A) general manager, Motor Products Corporation, *Detroit,* (mail) 11801 Mack Avenue.

MARSDEN, W. S. (J) assistant instructor in engineering mechanics, Sheffield Scientific School, Yale University, *New Haven, Conn.,* (mail) 1472 Chapel Street.

McCALMONT, JOHN C. (J) junior engineer, department construction and repair, Navy Yard, *City of Washington,* (mail) 1819 Adams Mill Road.

McCARTHY, OWEN E. (A) general manager of sales department, Pierce-Arrow Motor Car Co., *Buffalo.*

McCRAY, H. E. (M) chief engineer, Waterloo Gasoline Engine Co., *Waterloo, Iowa.*

McDAID, FRANK A. (A) assistant sales manager, C. Kenyon Co., Inc., *Brooklyn, N. Y.,* (mail) 310 Ridgewood Avenue.

McEVOY, JAMES (A) director of patent section, General Motors Corporation, Detroit, (mail) Dayton Engineering Laboratories Co., *Dayton, Ohio.*

McKAY, E. B. (A) president and general manager, Inland Rubber Co., 146 West 27th Street, *Chicago.*

MILBURN, SIDNEY ROBERT (A) truck and motorbus tire research and sales, B. F. Goodrich Rubber Co., New York City, (mail) *Mountain View, N. J.*

MOISSELLE, LOUIS (A) sales supervisor, David Lupton's Sons Co., Philadelphia, (mail) Room 526, 88 Broad Street, *Boston.*

MORIARTY, JAMES, JR., (A) service-manager, Williams & Hastings, *Detroit,* (mail) 9300 Broadstreet Boulevard.

MORRISON, J. A. (A) chief engineer and general manager, Woods Engineering Co., *Alliance, Ohio.*

MORVAN, CAMILLE P. (M) draftsman, Edward G. Budd Mfg. Co., *Philadelphia,* (mail) 3521 North Judson Street.

NICODEMUS, C. R. (A) service-manager, Studebaker Service Station, 1760 East 25th Street, *Cleveland.*

OLSEN, N. H. F. (M) designer, Ford Motor Co., Dearborn, Mich., (mail) 1952 Highland Avenue, *Detroit.*

OSTRANDER, A. E. (A) assistant vice-president, American Car & Foundry Co., 165 Broadway, *New York City.*

PATERSON, A. B. (A) vice-president, New Orleans Public Service, Inc., *New Orleans.*

PERDEW, W. E. (M) general manager of refining and marketing, Derby Oil Co., *Wichita, Kan.*

PLATT, HAVILAND HULL (M) chief engineer, Wilkening Mfg. Co., Philadelphia, (mail) *Wallingford, Pa.*

PORTER, RAYMOND EDWIN (S M) associate mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 1115 North Main Street.

RIEDEL, WALTER C. (J) automobile electrician, New York Telephone Co., New York City, (mail) 267 Palmetto Street, *Brooklyn, N. Y.*

RIPPLE, PAUL WOODMAN (A) chief engineer of power equipment, Connecticut Co., *New Haven, Conn.,* (mail) 132 McKinley Avenue.

ROME WIRE CO. (Aff.) 56 Clyde Avenue, *Buffalo.*
Representatives: Boss, R. W., experimental engineer,
Joos, H. C., district manager, Detroit,
Wodtke, Hans V., manager of Diamond branch.

SEEL, FRED (J) body engineer, International Motor Co., Long Island City, N. Y., (mail) 951 Jennings Street, *New York City.*

SHAPIRO, ALEXANDER (A) commercial manager, Wisconsin Motor Bus Lines, 426 Public Service Building, *Milwaukee.*

SHARPE, FRANK A. (A) district manager, Thermoid Rubber Co., Trenton, N. J., (mail) 511 Kresge Building, *Detroit.*

SICKELS, GEORGE H. (A) truck transportation manager, Mexican Petroleum Corporation, 164 Allens Avenue, *Providence, R. I.*

SIERK, HERBERT (A) 3853 Greer Avenue, *St. Louis.*

SIHLER, EDMUND V. (A) National Malleable & Steel Castings Co., Room 1420, 30 Church Street, *New York City.*

SMITH, GEORGE A. (M) technical editor, Motor Boat Publishing Co., *New York City,* (mail) 14 West 60th Street.

STERNBERG, WILLIAM G., JR., (M) president, Sterling Motor Truck Co., *New York City,* (mail) 839 Riverside Drive.

STERNER, JOHN J. (A) chief engineer, Murphy Varnish Co., Newark, N. J., (mail) 39 Fairbank Street, *Hillside, N. J.*

STEWART, JAMES (A) automotive engineer and salesman, Vacuum Oil Co., Ltd., Custom House Quay, *Wellington, N. Z.*

TORONTO HYDRO-ELECTRIC SYSTEM, (Aff.) 225 Yonge Street, *Toronto, Ont., Canada.*
Representative: Connor, A., superintendent of garage.

VAN DER STEMPEL, TH. M. (J) junior engineer, transportation department, Chicago Motor Coach Co., 4533 Wilcox Avenue, *Chicago.*

WAGNER, VICTOR W. (A) service representative, Studebaker Corporation of America, South Bend, Ind., (mail) 1805 East 19th Street, *Cleveland.*

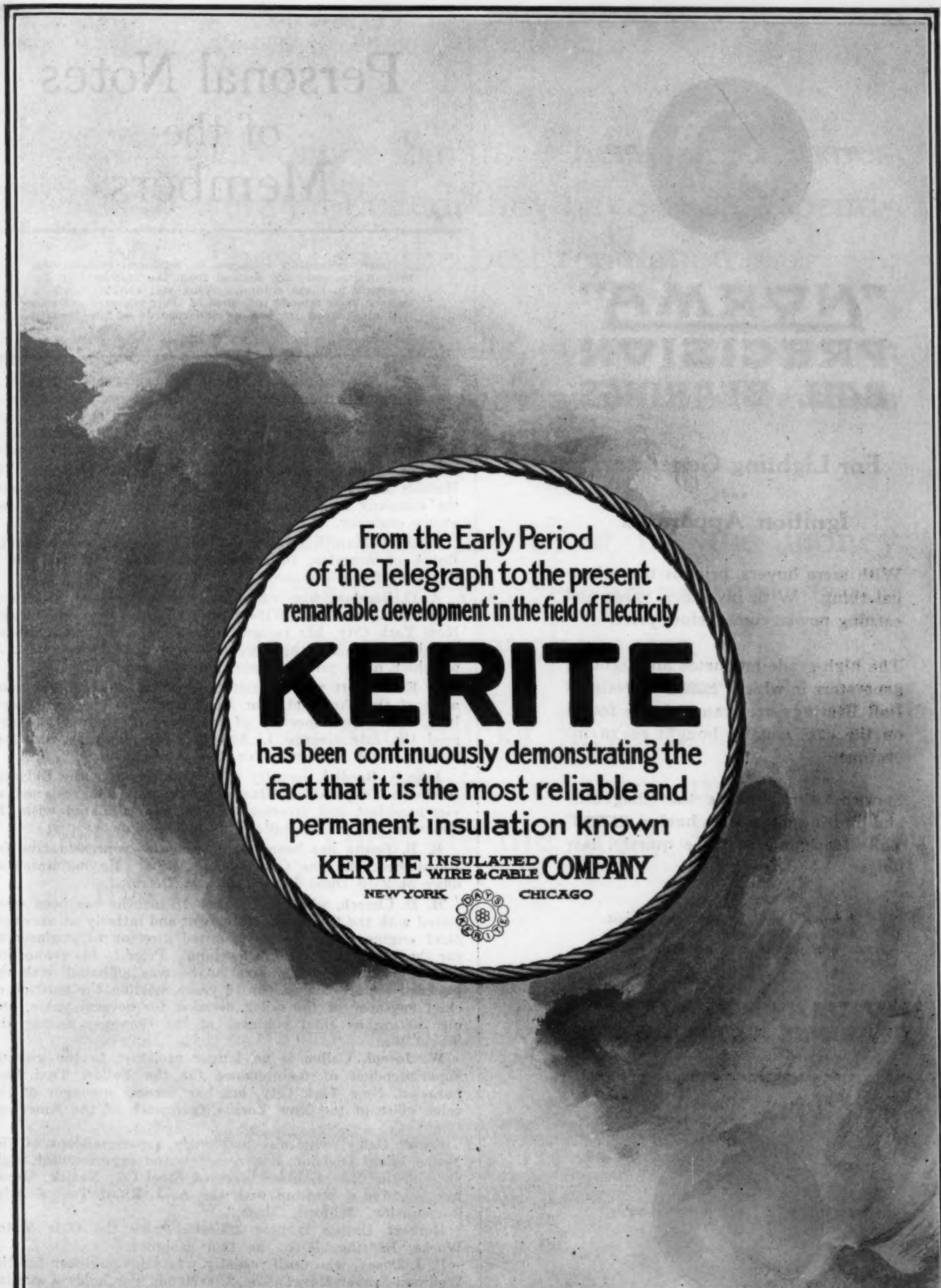
WEITZEL, WALTER H. (J) draftsman, Graham Bros., *Evansville, Ind.,* (mail) 728 Jackson Avenue.

WEST, FRANK RUSSELL (M) development engineer, T-N-T Engineering Co., *Newark, N. J.,* (mail) 67 Parkview Terrace.

WHEELER, ARTHUR L. (A) secretary, Eberhard Mfg. Co., 2734 Tennyson Road, *Cleveland.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

INDEX TO VOLUME XVI, JANUARY-JUNE, 1925



Personal Notes of the Members

Items regarding changes in business connections, promotions, etc., are desired from the membership for insertion in these columns. This will enable members to keep their friends informed of their whereabouts and will also assist in keeping the records of the Society up to date.

W. F. Barrett, vice-president of the Prest-O-Lite Co., New York City, received the honorary degree of doctor of science from the University of Pittsburgh, at the recent Charter Day exercises, in recognition of his achievements in the production and commercialization of industrial gases.

G. G. Behn recently resigned as chief engineer of the Hudson Motor Car Co., Detroit. He is still associated with the company in a consulting capacity with the title of advisory engineer.

L. J. Belnap has resigned as president of the Rolls-Royce of America, Inc., Springfield, Mass. He is still a director of the company.

A. C. Bigelow, who was formerly vice-president and general manager of the Wills Sainte Claire Co. of New York, New York City, has resigned his office with that company and has organized the Bigelow Supply Co., Trenton, N. J., of which he is president and general manager.

C. E. Bonnett was appointed secretary and general manager of the Tire and Rim Association of America, Cleveland, at a recent meeting of the board of directors, to succeed the late **George L. Lavery**. Mr. Bonnett was previously chief inspector for the Association.

John S. Burdick recently sold his interest in the Burdick-Atkinson Corporation, Hamburg, N. Y., and resigned as vice-president and director. He is now affiliated with the American Body Co., Buffalo, as chief engineer.

E. B. Busby has been appointed sales representative for Blood-Bros. Machine Co., Allegan, Mich. He maintains an office at 2315 Dime Bank Building, Detroit.

H. D. Church, who for the past 18 months has been associated with the Chevrolet Motor Co., and latterly as assistant chief engineer, has been appointed director of engineering for the White Motor Co., Cleveland. Prior to his connection with the Chevrolet organization he was affiliated with the Packard Motor Car Co. for 10 years, holding the position of chief engineer of the truck division for several years, and also acting as chief engineer of the Company during the World War.

W. Joseph Cullen is no longer assistant to the general superintendent of maintenance for the Yellow Taxi Corporation, New York City, but has become manager of the sales office of the New York City branch of the American Chain Co.

Frank Daley, who was previously superintendent of the Nepso Lamp Division, and research and experimental engineer of the New England Pressed Steel Co., Natick, Mass., has accepted a position with the A. J. Knott Tool & Mfg. Corporation, Milford, Mass.

Herbert Dalton is now affiliated with the Olds Motor Works, Lansing, Mich., as tool designer.

P. J. Dasey, who until recently was sales engineer for the Wellman-Seaver-Morgan Co., Cleveland, now holds a similar position with the Climax Engineering Co., Clinton, Iowa, and will make his headquarters in Tulsa, Okla.

(Continued on p. 4)

Personal Notes of the Members

Continued

E. H. Delling is now associated with Brooks Steam Motors, Ltd., Stratford, Ont. He was previously vice-president and chief engineer of the Delling Motors Co., West Collingswood, N. J.

C. E. Dwyer has been appointed general sales manager of the Six Wheel Co., Philadelphia. He was formerly sales engineer in the railway department of the Timken-Detroit Axle Co., Detroit.

James Dykstra, who was until recently affiliated with Brooks Steam Motors, Ltd., Stratford, Ont., has joined the engineering department of the Ford Motor Co., Dearborn, Mich.

Earl E. Eby is no longer assistant general manager of sales of the Hyatt Roller Bearing Co., Newark, N. J., but is associated with the Olds Motor Works, Lansing, Mich., in the capacity of assistant to the general manager.

Edward P. Edinger has resigned from the H. H. Franklin Mfg. Co., Syracuse, N. Y., to accept a position as shop engineer with the International Motor Co., Allentown, Pa.

Murray Fahnestock has been appointed technical editor of *Ford-Power-Age*, Milwaukee, in addition to being connected in a similar capacity with *Ford Owner and Dealer Magazine*, also of Milwaukee.

Edward A. Field is now associated with the Field Engineering Co., Chicago, in the capacity of president and engineer. This company recently took over the assets of the Four Fold Co., Ltd., also of Chicago, of which Mr. Field was president and manager.

Otto E. Fishburn has been made production engineer in the stamping division of the Murray Body Corporation, Detroit. He was formerly chief inspector for the J. W. Murray Mfg. Co., also of Detroit.

E. H. Gunster is no longer mechanical engineer for the Train Control Corporation of America, New York City, but is again affiliated with the Sheldon Axle & Spring Co., Wilkes-Barre, Pa.

Frank L. Main, who was formerly assistant sales manager in the steel wheel experimental department of the Hayes Wheel Co., Jackson, Mich., has been made consulting engineer for the General Motors Corporation, Detroit.

Glenn Muffly has been appointed special representative of the general manager on commercial research work for the Olds Motor Works, Lansing, Mich.

M. Nielsen, who was until recently assistant engineer for the Climax Engineering Co., Clinton, Iowa, has become affiliated with the Yellow Coach Co., Chicago.

F. Lee Norton has been elected vice-president of the Belle City Mfg. Co., Racine, Wis. Previously he was president of the Malboat Products Co., also of Racine.

Charles H. Osmond, who for the past 6 years has been associated with the Atlantic Refining Co., Philadelphia, in various capacities and more recently as chemical engineer, has formed a partnership to be known as Crandall & Osmond, to engage in the practice of consulting petroleum engineering, with offices in the Whitehall Building, New York City.

R. B. Palmer has severed his connection with the J. W. Murray Mfg. Co., Detroit, where he was factory manager. No announcement has been made of his future plans.

I. D. Rocap has been appointed general manager of Burgard's Garage, York, Pa. His previous business connection was with the Washington-Virginia Motors, Inc., City of Washington, as wholesale manager.

G. F. Roth, who was until recently factory manager for the Anchor Cab Mfg. Co., Cincinnati, Ohio, has accepted a position with the F. H. Lawson Co., also of Cincinnati.

(Concluded on p. 6)

PERSONAL NOTES OF THE MEMBERS

Concluded

H. M. Rugg has been made an assistant on the headquarters engineering staff of the automotive department of the Vacuum Oil Co., New York City. He was formerly in the experimental department of the dynamometer laboratory of Dodge Bros., Detroit, and more recently engaged in automotive research work for the Texas Co., New York City.

B. Russell Shaw, who was for 3 years executive vice-chairman of the Contest Committee of the National Aeronautic Association, City of Washington, has accepted a position to be in charge of ground organization for the Ford Airlines and the Stout Metal Airplane Co., Dearborn, Mich.

George C. Warner, who was formerly sales manager in the Pittsburgh district for the George D. Whitcomb Co., Rochelle, Ill., is now associated with Standard Steel & Bearings, Inc., Plainville, Conn., with headquarters in its Detroit office.

William S. Watts has accepted a position as draftsman for the Rockford Milling Machine Co., Rockford, Ill. Prior to this connection he attended Tri-State College, Angola, Ind.

E. W. Weaver has become affiliated with the George T. Trundle, Jr., Engineering Co., Cleveland, in the capacity of chief engineer in the automotive department.

Thomas J. Wetzel has been made president of the newly organized company known as Wheels, Inc., New York City, and **John F. Creamer** is associated with him in the capacity of treasurer and manager.

Stanley Whitworth is now factory manager of the plant at South Bend, Ind., of the Bendix Brake Co. He was formerly works manager for the Sheldon Axle & Spring Co., Wilkes-Barre, Pa. Previously he was associated with Nordyke & Marmon Co., and the Stutz Motor Car Co., both of Indianapolis.

Villor P. Williams, who was until recently consulting engineer for the Automotive Hydraulic Products Corporation, Baltimore, has been made president and consulting engineer of the Parkmobile Corporation, also of Baltimore.

James Wills is no longer mechanical draftsman for the Ruckstell Sales & Mfg. Co., New York City, but has become machine designer for the Powers Accounting Machine Corporation, New Brunswick, N. J.

O. A. Witte has resigned as secretary and chief engineer of the American Bureau of Engineering, Chicago. No announcement has been made of his future plans.

Alvin Yocum has become associated with the Multibestos Co., Walpole, Mass., as chief engineer in charge of its research and testing laboratory, and consulting on all brake and clutch problems.

See notice on page 28 regarding S. A. E. Employment Service

Notes and Reviews

This column, which is prepared by the Research Department, gives brief items regarding technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

Johnson's Materials of Construction. Rewritten by M. O. Withey and James Aston. Published by John Wiley & Sons, Inc., New York City. 865 pp.; illustrated.

Successful construction from the engineer's point of view is based largely on the materials used. Some 20 years ago J. B. Johnson, dean of the college of engineering of the University of Wisconsin, realized the need for a comprehensive treatise on this subject. He stated that the rational designing of any kind of construction involves a knowledge of the external forces to be resisted, transformed or transmitted; the internal stresses resulting therefrom; and the mechanical properties of the materials to be employed to accomplish the objects sought. This book, widely known as a text and reference book, is the result of his efforts.

As time has gone on, changes in practice and the development of new material, as the result of the great progress that has been made in recent years, has made it necessary to rewrite this work and at the same time rearrange the contents so that the material is more readily available.

Some of the subjects treated are: general nature of deformation and stress; materials under tensile, compressive, shearing, cross-bending and combined stresses and resilience. Another section is devoted to testing machines, such as compressive, transverse, cold-bend, shear and torsion, impact, endurance and apparatus for determining hardness. A number of appliances for measuring deformations are also discussed.

Several chapters have been devoted to iron and steel and their properties. Fatigue of metals and the corrosion of metals, paints and varnishes are also treated. The last chapter contains data relative to the constitution of some of the more important non-ferrous metals.

Accelerated Fatigue Tests and Some Endurance Properties of Metals. By D. J. McAdam, Jr. Published in the *Proceedings of American Society for Testing Materials*, Vol. 24, Part 2, p. 454.

To investigate the possibilities of the accelerated fatigue method, tests were first made on steels. Dimensions of specimen, radius of crank-pin motion, inertia of flywheel and frequency of oscillation were varied so as to obtain widely different ratios of total amplitude of oscillation to the amplitude of oscillation due to crank-pin motion. The investigation was then extended to non-ferrous metals, such as duralumin, hot-rolled nickel and hot-rolled monel metal.

The results obtained have been summarized by stress-cycle graphs showing both automatic and artificial changes of stress during the progress of each test. Stress-strain graphs for some of these accelerated fatigue tests have also been drawn for comparison with results obtained by the deflection method. For comparison with the fatigue method, some findings have further been plotted on a semi-logarithmic scale.

The Endurance Range of Steel. By D. J. McAdam, Jr. Published in the *Proceedings of American Society for Testing Materials*, Vol. 24, Part 2, p. 574.

In the experiments described five sets of nickel and one set each of carbon, carbon-vanadium and chrome-nickel steel specimens were tested. The percentage difference between the alternation endurance range and the endurance range when at the edge of the elastic range can be calculated from each of these eight sets of experiments. The average varia-

(Continued on p. 10)

NOTES AND REVIEWS

Continued

tion in endurance range of these steels within the elastic range was found to be less than 5 per cent. The average percentage variation for nickel steel is about the same.

As indicated by some results illustrated and by some experiments not recorded, a maximum exists beyond which the upper limit of the endurance range cannot be readily moved, any attempt to do this resulting merely in increasing the minimum stress without any increase in the upper limit of the range, at least until the endurance range has been considerably shortened. This maximum upper limit is called the endurance yield-point.

Some of the experiments apparently showed that not only within the elastic range, but even up to the endurance yield-point the variation of the endurance range of these steels is slight. In some experiments the upper limit of the endurance range was even moved much beyond the usual endurance yield-point of the material, with only a slight reduction in the endurance range. Such erratic variations in the endurance range beyond the elastic range need further study.

In closing, the author points out the practical value of the investigation in connection with the design of machinery parts that are subject to torsion fatigue. The findings, he says, will be of especial aid in the design of heat-treated alloy-steel shafting. For fatigue-resistant machinery parts, steel of high elastic-ratio as well as high tensile-strength is demonstrated to be superior.

The X-Ray Examinations of Steel Castings. By I. E. Moultrop and E. W. Norris. Published in *Mechanical Engineering*, May, 1925, p. 393.

At the present time this method of detecting flaws in steel is limited by the lack of suitable X-ray equipment. The commercial limit of 250,000 volts gives a maximum penetration of approximately 3 in. of steel. An operating voltage of 600,000 can be successfully applied which would give a penetration of about 6 in. Equipment necessary to give this voltage has not yet been developed.

Variations of density or thickness of 2 per cent can be definitely detected. Since the flaws of castings that are sufficiently important to warrant attention are equivalent to variations of 10 or 20 per cent or more, they can be discovered easily and their importance weighed.

The article groups the defects observable in steel castings in the following classes: gas pockets, sand inclusions, shrinkage flaws, cracks and arrowhead flaws. Radiographs picturing all these imperfections are given. The last part of the paper is devoted to a detailed description of specific work done in detecting flaws in castings. Articles found too defective for use were thoroughly checked in other ways. The X-ray findings were confirmed.

The Acid Corrosion of Metals. By W. G. Whitman and R. P. Russell. Published in *Industrial and Engineering Chemistry*, April, 1925, p. 348.

Part 1 of the paper presents an experimental survey of the effect of dissolved oxygen in the corrosion, by sulphuric, hydrochloric, nitric and acetic acids, of steel, aluminum, lead, copper, nickel, tin and several alloys. The method used was to compare the corrosion rates in two solutions, one saturated with oxygen and the other with hydrogen.

Part 2 deals with the effects of velocity on the corrosion of copper by sulphuric, acetic and hydrochloric acids. An apparatus in which the samples are suspended in the acid from a horizontal rotating wheel was used, and provision was made for air saturation or for total exclusion of oxygen.

The results emphasize the importance of oxygen in corrosion by dilute nonoxidizing acids. They also show that dissolved oxygen may act as a passivifying agent in some cases, thereby actually reducing corrosion. Velocity increases corrosion when oxygen is a vital factor, and also markedly accelerates corrosion where protective films may be removed.

(*Continued on p.* 12)

NOTES AND REVIEWS

Continued

Endurance Properties of Corrosion-Resistant Steels. By D. J. McAdam, Jr. Published in the *Proceedings of American Society for Testing Materials*, Vol. 24, Part 2, p. 273.

This paper gives the results of an investigation of endurance properties of corrosion-resistant steels, carried on at the Naval Engineering Experiment Station. The investigation covered is part of the general examination into the endurance properties of metals that has been in progress at this station for several years. In studying the corrosion-resistant steels, endurance tests have been made by the rotating-cantilever and the alternating-torsion methods. The endurance properties thus obtained have been compared with the results of static tension and torsion tests.

The rotating-cantilever and the alternating-torsion testing machines were the same as those used in previous experiments. The specimens used, however, were changed to some extent. The tapered portion in the new rotating-cantilever specimen was reduced in length to 2 in. to avoid breaking at the outer fillet. In the alternating-torsion specimen, the effective test length was increased to provide for tests by the deflection method and by the accelerated fatigue method described in the article.

Six stress-strain curves show the results of the tension tests. The findings in the static-torsion tests are given in a table, and the results of the rotating-cantilever endurance-tests are summarized in six graphs drawn by semi-logarithmic plotting. The results of the alternating-torsion tests are also illustrated in a graph.

The Practical Use of Laboratory Corrosion Tests. By W. E. Pratt and J. A. Parsons. Published in *Industrial and Engineering Chemistry*, April, 1925, p. 376.

The kind of corrosion data furnished on typical acid-resisting metals is tabulated. Present information is said to be inadequate, and the desirability of additional work on tests and standardization of methods is stressed. The article then describes an apparatus and method of testing that have proved satisfactory.

The use of accelerated tests in metallurgical control work is shown to be practical under certain conditions and the deviation of results of accelerated tests from those of long experience is explained by the electrolytic theory. Typical corrosion curves are given, showing

(1) Initial losses at higher rate than constant loss after 24 hr.
(2) Error in predicting life of apparatus based on accelerated tests.
(3) The use of constant loss rate in approximating depth of corrosion or penetration in inches per year.
(4) The establishment of a factor to interpret the short accelerated test to the results of the constant loss rate of corrosion.

Accelerated corrosion tests are practically applied to show the effect on corrosion by changing the physical properties of the metal and the effect on corrosion of changes in the chemical composition of the alloy.

Aluminum and Its Light Alloys. By Robert L. Streeter and P. V. Faragher. Published in *Mechanical Engineering*, May, 1925, p. 433.

The data presented in this paper are the minimum properties ascertained by numerous tests of commercial material, as distinguished from data obtained from laboratory experiments. The author aims to give a survey of the place of aluminum alloys in industry, their treatment and their characteristics. The three methods of casting, sand casting, permanent-mold casting and die-casting, are described, and their field of usefulness indicated. The properties of aluminum alloys when treated by each of the three methods are tabulated, and typical examples of the finished products are shown. In describing the accuracy of the various processes,

(*Continued on p.* 14)

NOTES AND REVIEWS

Continued

the author says that for die-castings tolerances are discussed in thousandths of an inch; for permanent-mold castings, in thirty-seconds and sixty-fourths; while for sand castings, tolerances are considered in eighths and sixteenths.

Wrought aluminum, in which commercially pure metal is used, and strong alloys are then taken up. In the latter group are included the 17S and 25S alloys that are used in airplane and automobile construction.

Corrosion of Some Cast Aluminum Alloys and a Method of Protection. By A. C. Zimmerman. Published in *Industrial and Engineering Chemistry*, April, 1925, p. 359.

Difficulties that have been encountered owing to the corrosion properties of aluminum alloy parts when used in the fuel systems of aviation engines are briefly mentioned. The article gives in detail the procedure and results from a series of tests to obtain alloys that would reduce the corrosion to the minimum and protective coatings that would practically eliminate it.

The silicon-aluminum alloys were found to be the most resistant to water corrosion, and a sodium silicate or Z-D process treatment gave the best results as a protective coating. This treatment answers a twofold purpose in that it not only inhibits corrosion but also reduces the porosity of the castings. It is now used extensively by the Air Service for the protection of cast aluminum parts that are exposed to corrosive media.

Metallurgical Research in England. By Dr. Walter Rosenhain. Published in *The Iron Age*, April 2, 1925, p. 975, and April 16, p. 1128.

The metallurgical research at the National Physical Laboratory, Teddington, England, is a continuation of the work previously carried on by the alloys research committee of the Institution of Mechanical Engineers. The National Physical Laboratory, which it is now widely known, was founded in 1901 and Dr. Rosenhain's connection with the metallurgical department dates from 1906.

A scientific staff of more than 30 is now engaged in the work of the metallurgical department, with a force of other grades totalling more than 80 persons. Extensive laboratories, a foundry and a rolling mill make up the equipment. The laboratories consist of a series of small rooms, each arranged for a specific kind of work, so that all types of operation can be carried out in detail without interference.

The microscopic equipment is characterized as widely different from that in any American metallurgical laboratory. It was designed by Dr. Rosenhain and its main feature is a tube fixed rigidly to the limb of the stand, all focussing being done by movements of the stage. An optical leveling device enables the operator to mount specimens accurately in 4 or 5 sec. In connection with the gradient furnaces another piece of special equipment is mentioned. This is the plotting chronograph, with which the thermal curve observations are registered. This instrument, it is claimed, records with much more accuracy and delicacy than the photographic or mechanical devices commonly used.

Besides studying the constitution of alloys by the complete equipment described, the National Physical Laboratory has also investigated their physical and mechanical properties. To prepare the specimens in the relatively large quantities needed for this work, a small foundry and rolling mill are maintained.

Investigations carried on include pure research; researches undertaken for the solution of industrial problems, the expense of which is usually borne by the industry benefited; and examinations into specific works problems. The following specific projects that have been carried out are enumerated: (*a*) investigations on the behavior of metals under plastic strain and fatigue; (*b*) the production of pure metals

(*Continued on p.* 16)


CARTER
Trimmings & Mouldings
Proof of Quality by Dominance
For twenty-five years, the name of Carter, throughout the upholstery trade has meant the best in trimmings, furnishings and mouldings. The result of this accumulated experience is offered freely to the motor car and body builder desirous of improving his product without undue expense.
The Geo. R. Carter Co.
Connersville, Ind.
WIRE ON PRODUCTS
U.S. Patent, Aug. 16, 1921; Canada Patent July 25, 1922. Additional and Foreign Patents Pending

NOTES AND REVIEWS

Continued

and alloys for the redetermination of their physical constants; (*c*) the effects of impurities on copper; the determination of oxygen in aluminum; (*d*) the study of special high-tensile brass alloys; (*e*) die-casting of aluminum alloys; and (*f*) dental alloys and amalgams.

Gasoline. By T. A. Boyd. Published by Frederick A. Stokes Co., New York City. 211 pp.; illustrated.

This book is written in a popular vein. Its purpose is to tell the user of gasoline what the nature of this fuel is, where it comes from, how it is prepared, how to extract from it its utmost benefits, and how to avoid its dangers.

In a preliminary chapter, the history of the automobile is touched on. Oil production is the next topic. In the 65 years since oil pushed its way slowly through the first shaft sunk, it is said, more than $12,500,000,000 has been spent in the actual work of developing oil fields of the United States. The present status of oil production in this country is summarized in the following figures: 22,000 oil wells completed in 1924, at an estimated cost of $475,000,000; and, at present, a total of 275,000 producing oil wells with an average output of 7 bbl. a day. A description is given of cracking and refining processes and of the methods of recovering casinghead or natural gasoline from natural gas.

Driving at a speed of 20 m.p.h. is recommended as one method by which the motorist can obtain the maximum efficiency from his fuel. Other practical suggestions are made as to the economical use of gasoline, and the avoidance of the dangers of fire and carbon monoxide poisoning.

An optimistic view is taken of the future fuel supply. Even if the petroleum fields of the United States are exhausted, Mr. Boyd points out, automobile fuel may be obtained from oil shale, or, in the form of alcohol, from vegetation.

Dew Points of Gasoline-Air Mixtures. By D. P. Barnard, 4th, and R. E. Wilson. Published in *Industrial and Engineering Chemistry*, April, 1925, p. 428.

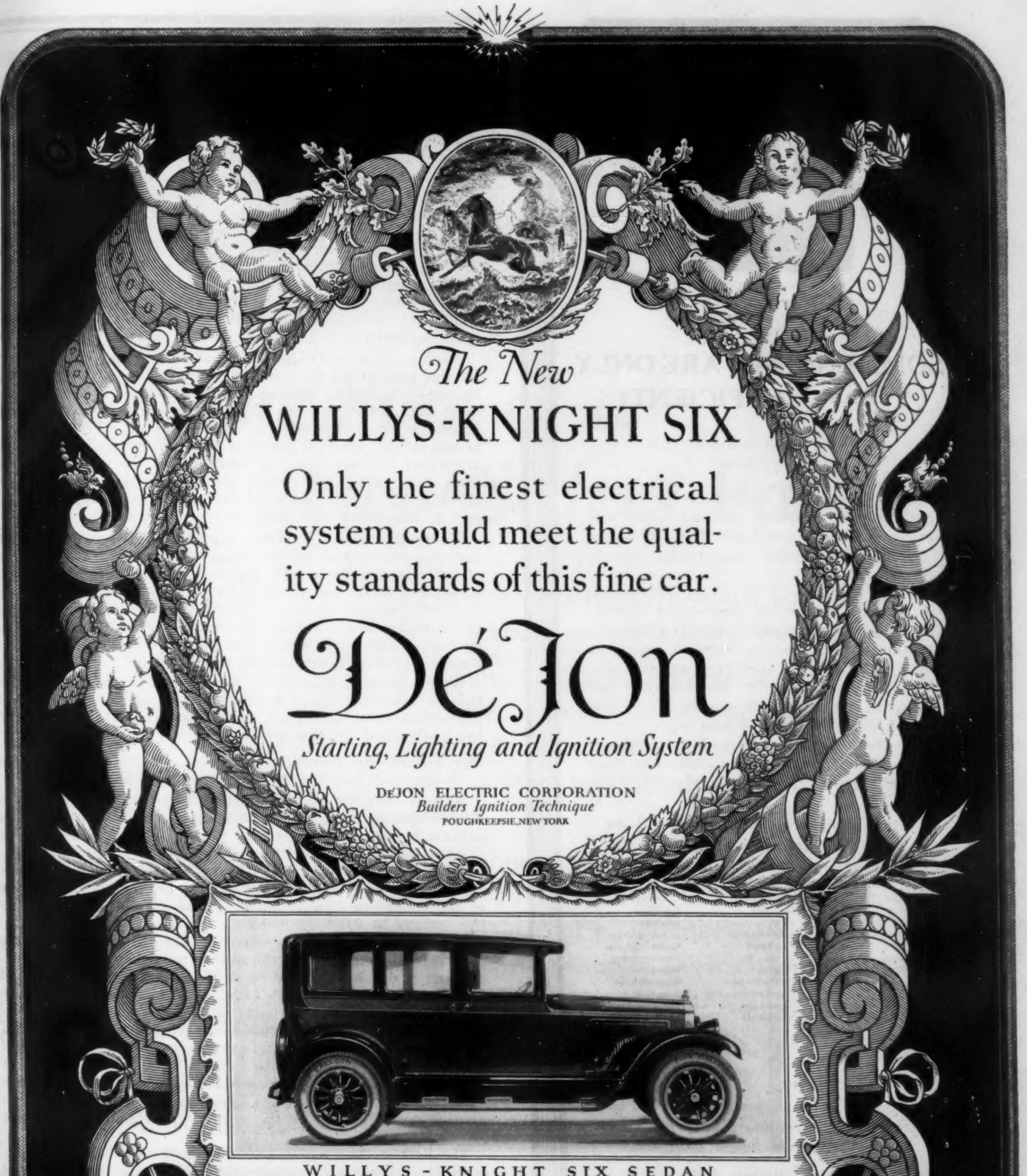
In two previous papers the authors gave the results of some experiments in determining the dew points of gasoline-air mixtures. In these the vapor-pressure method had been used. Later Gruse by a direct method fixed dew points for identical fuels from 20 to 30 deg. cent. (36 to 54 deg. fahr.) higher. The present paper explains these discrepancies. They are due to the difference in the composition of the equilibrium solution prepared at atmospheric pressure, as used by the authors, and one prepared at the low pressures corresponding to those in the manifold. The vapor-pressure method will give correct values if the equilibrium solution is prepared at these low partial pressures, but to do this is difficult. The direct method of Gruse is simple and accurate. It does not, however, yield all the information given by the vapor-pressure method.

The 85-per cent point is still believed to constitute the best single measure of the effective volatility of a fuel from the standpoint of manifold distribution and crankcase-oil dilution. The dew point may be obtained with accuracy sufficient for most purposes by comparing the 85-per cent point with a graph showing the dew points of 12:1 air-fuel mixtures.

Carburetion. By D. Finlayson. Published in *The Automobile Engineer*, April, 1925, p. 114.

This article is not intended to be a general survey of the carburetion problem but is confined to those fundamentals of the carburetion process which have only recently received the attention they deserve, dismissing briefly those items of carbureter performance which are well appreciated in the industry. The paper is roughly divided into two parts, the first of which deals with the carbureter as a metering device, and the second covering its function as a vaporizing device. A short discussion of carbureter efficiency concludes the

(*Continued on p. 18*)


The New
WILLYS-KNIGHT SIX
Only the finest electrical system could meet the quality standards of this fine car.
DéJon
Starting, Lighting and Ignition System
DeJON ELECTRIC CORPORATION
Builders Ignition Technique
POUGHKEEPSIE, NEW YORK
WILLYS-KNIGHT SIX SEDAN

NOTES AND REVIEWS

Continued

treatise. One branch of the carburetion problem, that of equable distribution to multi-cylinder engines, is not touched on.

On the topic of a carbureter as a metering device, the author first takes up engine requirements. He draws the conclusion that when carburetion and distribution are good, the maximum-power mixture is about 20 per cent richer than the chemically correct mixture and almost independent of speed or load, and that the maximum-economy mixture becomes richer with decreasing load. He develops the characteristic curve of an ideal carbureter, under ideal running conditions, and then points out how the ideal characteristic must be modified to suit conditions of practice.

His next care is to show to what extent the ordinary carbureter can satisfy these requirements. The factors affecting the flow of liquids through jets and orifices are explained, and characteristic curves of different jets are illustrated in graphs. Some discussion is devoted to the effects of temperature and different types of fuel and several methods of analyzing the operation of carbureter jets are described. Very few carbureters, says the author, may claim to be automatic if the criterion of performance is supplying correct mixtures for all conditions.

Under the second heading, vaporization, several tests for deriving the initial condensation-temperatures of mixtures of hydrocarbon fuels with air are detailed. Atomization is a valuable aid to vaporization, but can be effective only when the conditions are such as to allow the finely atomized drops to remain in that condition for a reasonable length of time. In many carbureter designs the preservation of the drop in its original form is not sufficiently considered.

At the close of the article three ways of estimating carbureter efficiency are described: (*a*) a comparison of work performed with fuel used, (*b*) Ricardo's method, and (*c*) the analysis of exhaust gases.

Our Future Oil Reserves. By C. A. Fisher. Published in *Mining and Metallurgy*, April, 1925, p. 178.

At least five different estimates of the oil reserves of the United States have been made by both Government and private agencies in the last 16 years. The figures given as a result of these surveys vary from 5,000,000,000 to 15,000,000,000 bbl. The last, and presumably the best guided calculation, made by Government geologists and representatives of the American Association of Petroleum Geologists, places the reserve at 9,000,000,000 bbl.

After reciting figures comparing the estimated available reserve with consumption the author points out that the percentage of dry holes found by drilling has steadily increased from 16.7 in 1913 to 22.6 in 1924. This has occurred in spite of better geological knowledge at the disposal of the prospectors and is due to the growing scarcity of good unexplored fields. In the same time the average cost of drilling a well has more than doubled, both because of increase of cost of material and labor and because of the greater depth necessary to obtain a product. These conditions will lead to greater unwillingness on the part of individuals to prospect for new wells.

The author then makes the statement that based on conservative estimates of consumption, the entire reserve would be exhausted by 1933, if it were possible to produce the oil that rapidly. After dismissing as inadequate various other substitutes for petroleum, he turns to the consideration of oil shales, which, in his opinion, provide insurance for a supply of oil sufficiently elastic to quiet the fears of the most far-sighted statesman, oil producer or investor. From the oil shale in four States, according to estimates, 75,135,621,400 bbl. of recoverable oil can be obtained.

Grinding Practice. By H. A. Dean. Published in *The Automobile Engineer*, March, 1925, p. 73.

This article, which is a resume of a paper presented be-

(*Continued on p. 20*)

NOTES AND REVIEWS

Continued

fore the Institution of Production Engineers, enumerates the types of grinding, describes methods that can be used to further efficiency in this work and tells about certain machines used in grinding.

The most common class of precision grinding, the author points out, is the production of cylindrical parts. The relative merits of a traveling work table and a traveling wheel for this work have been much discussed. The point to be considered in making a decision is whether the work is so heavy that more power would be required to move it or to move the wheel head. A difficulty often met with in grinding aluminum, he says, is the scratching of the surface of the work. These marks are made by aluminum chips that float in the cooling lubricant and return through the pipe. A suggested remedy is to place a filter over the pump entrance in the tank, and to use as a lubricant a mixture of lard oil and paraffin in the proportion of 1 to 10. The importance of steady rests in achieving efficient production is also emphasized.

A comparatively new development in cylindrical grinding is centerless grinding, the principal elements being a grinding wheel, a feed wheel and a work rest. This method assures a continuous passage of parts across the wheel and eliminates the time lost in dogging and centering the work.

In speaking of cam grinding, the author gives as the work speed required for roughing integral camshafts about 60 r.p.m., and for finishing, 15 r.p.m. A caution against using wheels with lead bushes for internal grinding is voiced, for the reason that lead bushes in small wheels, traveling at high speed, are apt to cause vibration and wear wheels down quickly; and to get greater output is better than to save on wheels and slow down production.

Cylinder grinding is next taken up. In this connection the author stresses the importance of accurate grinding methods in automobile manufacture. The cylinder being the fundamental component of the automobile engine, the efficiency of the whole mechanism lies to a great extent in the proper grinding of this part. Dry grinding is endorsed and a recommendation is made that to keep a uniform temperature, water be run in the jacket or over the outside of the cylinder.

Some specific instances are then given of the time taken to perform grinding work in an automobile factory. Gear grinding and surface grinding are the final topics dealt with.

Automotive Jigs That Save Time. By J. Gustaf Moohl. Published in *Machinery*, April, 1925, p. 641.

In the cylinder-block department using the jigs described in this article, the average reloading time of all jigs is 12 sec. Three types of jig are presented in detail and illustrated; one employed in drilling holes in the bottom of the cylinder-block, another used in reaming the valve-seat and the valve-guide holes, and a third for finish-boring the cylinders. The first jig, besides drilling 16 holes in the bottom of the cylinder, two of them with a combination drill and reamer, also incorporates several devices which insure that the cylinder-block is properly located and which indicate whether it was cast properly in the foundry. The two reamed holes are used for locating purposes in subsequent operations.

Standard interchangeable slip bushings are used wherever possible and the design of the different jigs is kept as closely alike as possible. In a number of cases the only substantial differences are in the arrangements of the jig bushing plates. By this means great economy is achieved.

Whirling Shafts. By J. Morris. Published in *The Automobile Engineer*, March, 1925, p. 83.

This is a general discussion of the behavior of whirling shafts, without any attempt to draw a definite conclusion. The author points out that the introduction of the De Laval turbine focussed attention on the behavior of a shaft at high speeds of revolution. Experiments showed that at certain speeds violent instability occurred, and that if these speeds

(*Continued on p. 22*)

NOTES AND REVIEWS

Continued

were maintained the shaft failed. Further, if these speeds were quickly negotiated, the shaft ran true and steady again. Such speeds were called critical speeds of whirling, and their investigation has engaged the attention of a number of writers, the subject now being regarded as one of great importance. The author then summarizes the findings of a number of writers on this subject, and gives examples to illustrate their theories. Objections are raised to most of the theories advanced, but those of Prof. W. McF. Orr are substantially endorsed. Professor Orr assumes that each element of the shaft revolves about its own axis and that the shaft does not normally rotate bodily around the axis of the bearings.

Torsional Vibrations and Critical Speeds of Shafts. By Arnold Lack and Charles B. Jahnke. Preprint of paper presented before the 1925 Spring Meeting of American Society of Mechanical Engineers, 27 pp.

This paper is an analysis of torsional vibrations and critical speeds of shafts. These magnitudes can be calculated, as shown here, for any engine when all necessary data are given. The various characteristics of torsional vibrations are measured with a special instrument called the Torsiograph, which shows on torsiograms the degree of irregularity of rotation.

The stresses in the shaft due to its vibrations are also computed, and means of avoiding dangerous vibrations are shown. Results of tests are given which were performed on; (*a*) an apparatus for demonstration of torsional vibrations, (*b*) an experimental horizontal oil engine, (*c*) a vertical two-cylinder Diesel engine driving two generators and (*d*) a vertical four-cylinder marine engine.

Laboratory Tests on Finishes. By H. C. Mougey. Published in *Industrial and Engineering Chemistry*, April, 1925, p. 411.

The author expresses the opinion that, in addition to laboratory tests of separate coats, all new automobile finishes should be tested by exposure to standard conditions and by service tests on cars. In any laboratory test that is designed to measure serviceability, the entire system of coats should be considered as a whole. This requires a consideration of the properties of each coat, the relation of the coats to each other, the methods of application and drying time and the service expected of each finish. Even where tests are carefully planned, they are often valueless because they do not measure the power of resistance to conditions encountered in service but merely indicate the reaction to the specific conditions of the test. The accelerated tests of finishes, in which the ultra-violet light is used, are described and characterized as merely identification tests. That is, they can be depended upon only to classify finishes according to the way in which they react to the tests.

Aerodynamic Characteristics of Airfoils at High Speeds. By L. J. Briggs, G. F. Hull and H. L. Dryden. National Advisory Committee for Aeronautics Report No. 207. Published by National Advisory Committee for Aeronautics, City of Washington. 17 pp.

The report deals with an experimental investigation of the aerodynamical characteristics of airfoils at high speeds, carried out jointly by the Bureau of Standards and the Ordnance Department of the Army. Lift, drag and center of pressure measurements were made on six airfoils of the type used by the Air Service in propeller design, at speeds ranging from 550 to 1000 ft. per sec. The results show a definite limit to the speed at which airfoils can be used efficiently to produce lift, the lift coefficient decreasing and the drag coefficient increasing as the speed approaches that of sound. The change in the lift coefficient is large for thick airfoil sections, having a camber ratio of 0.14 to 0.20, and for high

(*Continued on p. 24*)

NOTES AND REVIEWS

Continued

angles of attack. The change is not marked for thin sections of a camber ratio of 0.10 at low angles of attack for the speed range employed. At high speeds the center of pressure moves back toward the trailing edge of the airfoil as the speed increases. The results indicate that the use of tip speeds approaching the speed of sound for propellers of customary design involves a serious loss in efficiency.

Characteristics of a Single-Float Seaplane during Take-Off. By J. W. Crowley, Jr., and K. M. Ronan. National Advisory Committee for Aeronautics Report No. 209. Published by National Advisory Committee for Aeronautics, City of Washington. 11 pp.

At the request of the bureau of aeronautics, Navy Department, the National Advisory Committee for Aeronautics is investigating at Langley Field the planing and get-away characteristics of an N-9H, a DT-2 and an F-5L seaplane, as representing respectively a single-float, a double-float, and a boat type of seaplane. This report covers the investigation conducted on the N-9H. The results show that a single-float seaplane trims aft in taking-off. Until a planing condition is reached the angle of attack is about 15 deg. and is only slightly affected by the controls. When planing it seeks a lower angle, but is controllable through a widening range until, at the take-off, angles of from 8 to 15 deg. can be obtained with corresponding speeds of from 53 to 41 m.p.h. or about 40 per cent of the speed range. The point of greatest resistance occurs at about the highest angle or a pontoon planing angle of 9½ deg. and at a water speed of 24 m.p.h.

Reliability of Aircraft Engines. By J. D. Siddeley. Published in *The Journal of the Royal Aeronautical Society*, March, 1925, p. 132.

Accepting the British Air Ministry official type test as a measure the standard of reliability in airplanes has at least doubled since 1910, says this author. The period elapsing between complete overhauls has been increased by 350 per cent. In this time, also, the brake mean effective pressure has been increased by 75 per cent, the piston speed has increased up to 100 per cent, brake thermal efficiency has been increased by 33 per cent, and the weight per brake horsepower has been decreased by 170 per cent. The above figures are derived from tables given, which list the chief airplane engines and their characteristics as they were in 1910, 1914, 1922 and 1924.

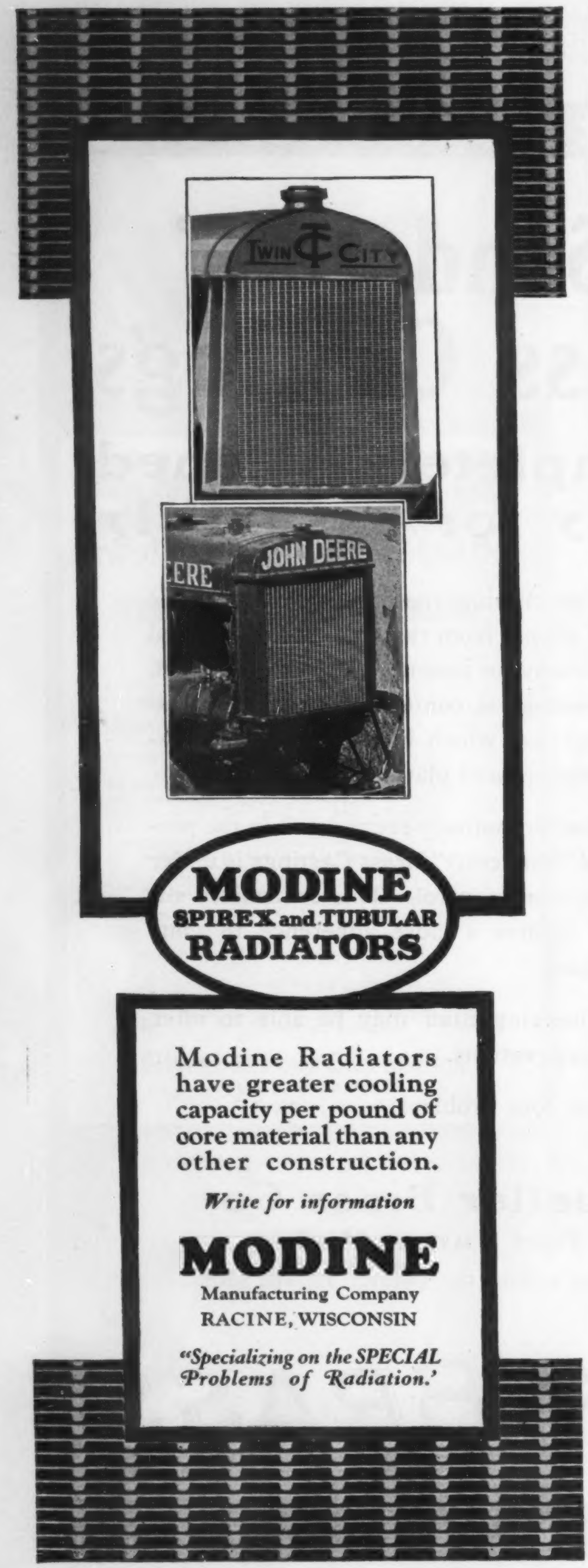
At the present time, a considerable amount of mechanical unreliability can be directly attributed to the use of unsuitable compression-ratios. The water circulating system of the water-cooled type has not only resulted in mechanical, but very frequently in functional, troubles. After outlining the causes of failure due to the different parts of the engine, the author draws the conclusion that future airplane engines should have forgings or pressed-steel parts substituted for bulky and stressed castings, should employ forgings that are small relative to the duty performed and should eliminate water or indirect cooling.

Stereophoto Surveying from the Air. Published in *Engineering News-Record*, April 9, 1925, p. 604.

A new process of airplane photographic surveying, known as the Brock process, is described. The claim is made that it produces true-scale maps, with or without contours, and that in practice contours can be located with confidence of their accuracy within limits of 1 ft. plus or minus. Essentially the process is a combination of a careful analysis of the differences between maps and pictures and the development of instruments for carrying out the transfer between the two rapidly and accurately.

Two pieces of information must be obtained on the ground: first, a known base line at the beginning and end of the survey network, or at intervals of 15 or 20 m. (49.21 or 65.62

(*Concluded on p. 26*)



NOTES AND REVIEWS

Concluded

ft.) in a long network; and second, the differences of elevation of four points in the field of each pair of plates. A pair of plates consists of two photographs taken from different positions of the airplane, but having overlapping fields. These must be used in conjunction in determining the location and elevation of points in the field of survey.

The photographs are taken in approximately horizontal position, and the error from horizontality is calculated from the plates themselves by differences of displacement of the four control points. The plates are then corrected to true horizontality by rephotographing them at the angle of tilt. The next step is to determine the elevation of all the points of the survey area by measurements of the same kind as those first used in determining the tilt. Finally, the contoured plate, which is a conic projection, and therefore not uniform in scale, is transformed by a replotting method to a true-scale orthographic projection, or map.

These operations are all made relatively rapid and easy by special methods and mechanical devices. A stereoscopic measuring table of high precision is one of the instruments specifically mentioned.

Automotive Electricity. By Earl L. Consoliver. Published by McGraw-Hill Book Co., Inc., New York City. 664 pp.; illustrated.

This book is designed to serve as a text for students who desire to specialize in automotive electrical and battery service work. It is also of such nature as to be of practical value as a reference book for automotive service-stations and their employes. It includes in its scope the electrical equipment of automobiles, tractors, trucks, motorcycles, motorboats, aircraft and stationary engines.

The plan of the book is to deal separately with each type of electrical equipment. First the general principles that govern its operation are discussed, then the application of these principles to typical instruments, and finally the detail refinements in different makes now on the market. Operation, the troubles likely to arise during use and the methods of detecting and correcting them are described.

An idea of the scope of the book may be obtained from a few of the 30 chapter headings: Fundamentals of Electricity, Ignition Requirements of Automotive Engines, Spark-Plugs, Typical Battery-Ignition Systems, Low-Tension Magnetos, High-Tension Magnetos, Ignition Equipment Troubles and Adjustments, Storage-Battery Construction and Operation, Lighting Equipment and Wiring, Elements of Starting and Generating Equipment, Starting Motors and Starting Generators, Typical Starting and Lighting Systems and Automotive Electrical Testing Instruments.

The book is clearly and simply written. The many illustrations, both photographs and diagrams, are a decided aid to the understanding of the subject. They illustrate many articles now in use and so add to the practical value of the book.

Cost and Earnings of Bus Service by Electric Railways. By Edmund J. Murphy. Published in *Aera*, April, 1925, p. 1463.

This summary and analysis of motorbus operations of electric railways is based on the reports of 45 companies, which own a total of 564 vehicles. During 1924 they took in $3,491,800 in bus operating revenue. These are the only items reported consistently by all companies. Forty-four companies report 806.5 miles of route over which they operated 15,972,552 motorbus miles. The total number of passengers carried was reported by 43 companies as 47,852,899. Included in the article are tables showing in detail financial and operating statistics of motorbus operation in 1924, and an analysis is made of the factors that determine the success or failure of such enterprises.

S. A. E. Employment Service

The Society has determined that it can assist its members to better advantage in the matter of employment service by discontinuing the notices of Men and Positions Available, formerly published in THE JOURNAL, and establishing instead a system of Semi-Weekly Bulletins, to be sent to members upon request.

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When beauty is combined with great strength and light weight—as in Dayton Steel Wheels—is it any wonder that large fleet owners insist upon Dayton Steel Wheels and nearly all leading truck makers use them?

THE DAYTON STEEL FOUNDRY COMPANY, Dayton, Ohio

Dayton
Steel Truck Wheels

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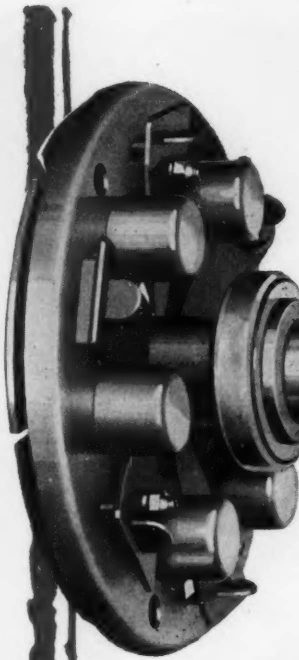
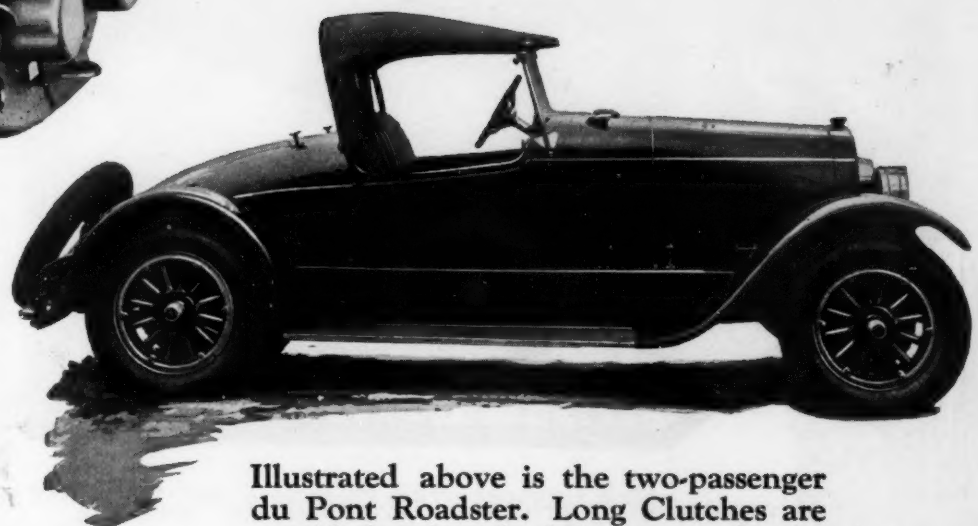
TIRE ECONOMY—ACCESSIBILITY—APPEARANCE



LONG



Illustrated above is the two-passenger du Pont Roadster. Long Clutches are specified as Standard Equipment for the entire du Pont line.

Long Products—Clutches and Radiators

The Yellow Coach Manufacturing Company, one of the leaders in the Motor Bus field, is using Long Radiators.

Pictured below is the Yellow Coach Parlor Car together with the Long Radiator used.

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DETROIT - MICHIGAN

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EXPERIENCED bus operators have learned that a profitable bus begins with equipment of Goodrich Silvertown Heavy Dutys, and never leaves it. These mighty pneumatic tires, built expressly for bus transportation, with especially rugged construction and genuine anti-skid traction, deliver a matchless service on buses.... These are not boastful statements. They are found in letters written by bus operators who have used Heavy Dutys and have seen them figure in the profit earned.

To round out economical and efficient service in the operation of trucks and buses, Goodrich provides the famous De Luxe cushion smooth type, Goodrich Semi-Pneumatics and Goodrich Silvertown Heavy Duty Cords.

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Today this ring is being used as standard factory equipment by more than 100 manufacturers. They realize that it embodies the highest standards of accuracy that have been attained in piston ring manufacture. It prevents oil-pumping and seldom fails to give 1000 or more miles to the gallon of oil. Write for samples and complete information regarding the PERFECT CIRCLE principle of *oil-regulation*.

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Buyers of heavy-duty trucks want lighting equipment of proved dependability
Owners and operators are favorably inclined towards heavy-duty trucks with equipment that they know will reduce maintenance and increase serviceability. Prest-O-Lite Gas answers these requirements. It is often a factor in closing the sale, as this letter from the Merritt Lumber Yards, of Reading, Pa., proves:
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Legal everywhere.
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LOCKHEED

Four Wheel Brakes

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In each Schrader Valve Inside is the rubber seat washer shown in red above. This is the vital part, the very heart, of the valve inside.

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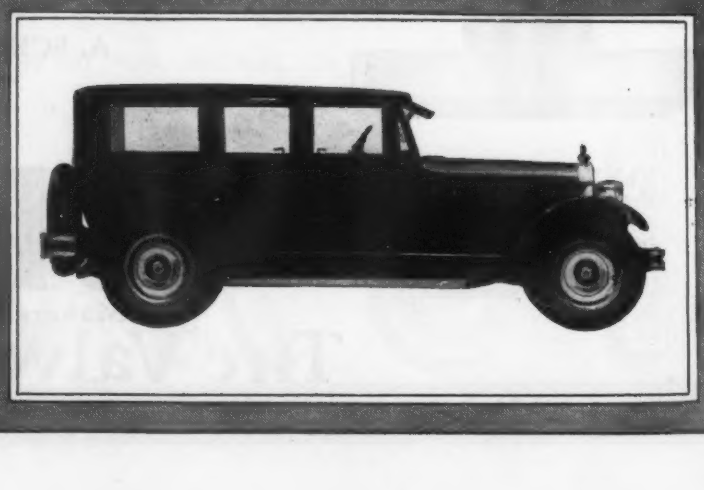

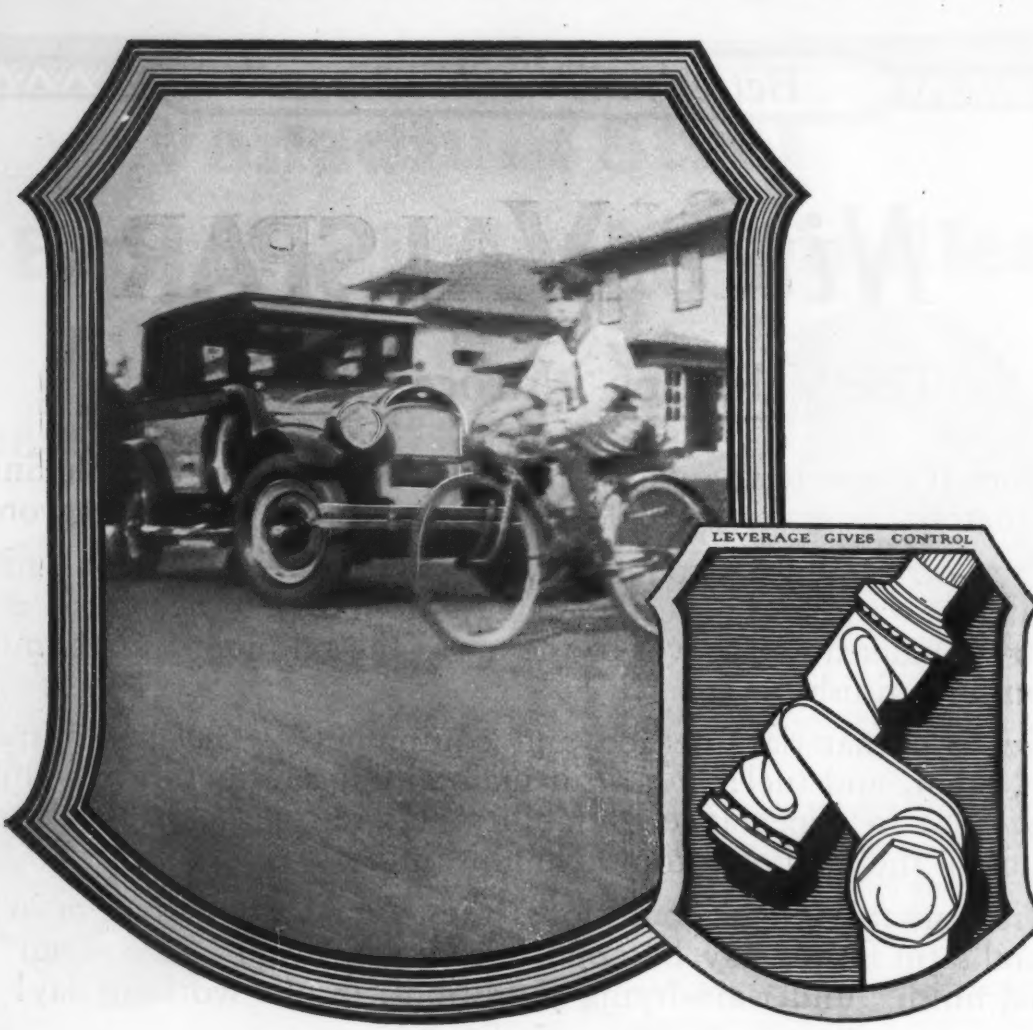
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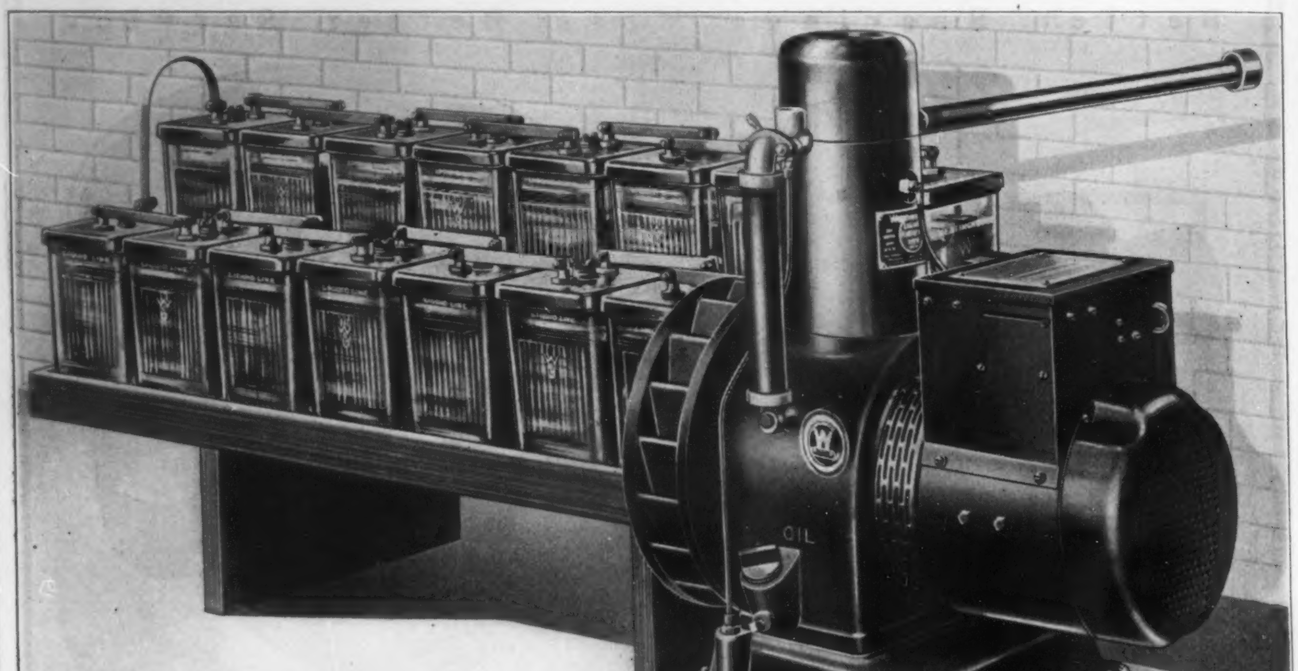
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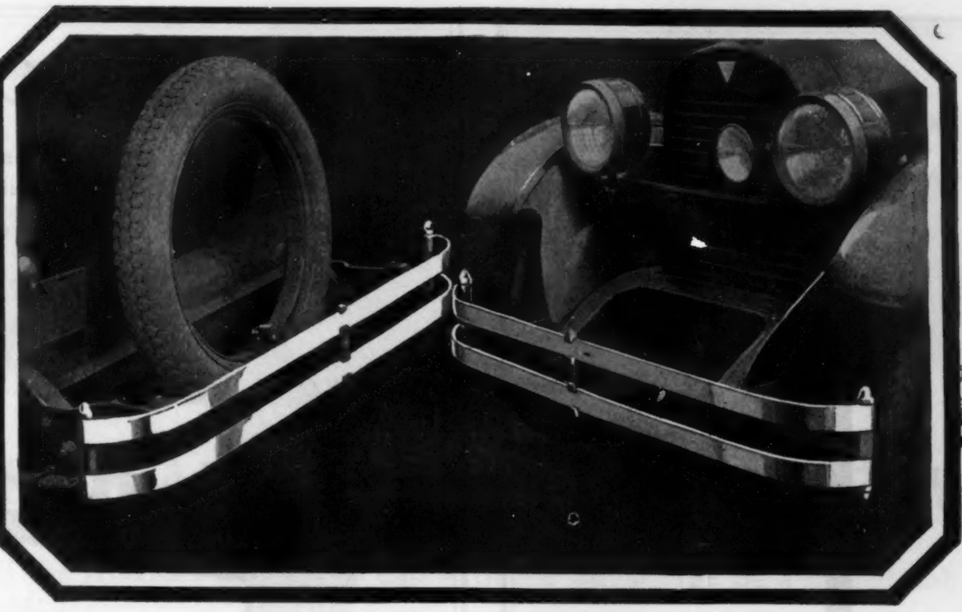

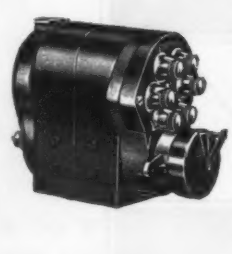

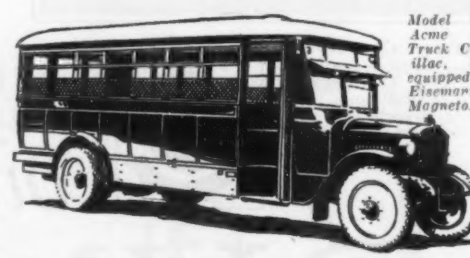


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Bands, Steel, D74
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Bars, Bronze
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*Electric Storage Battery Co.
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*Electric Storage Battery Co.
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Parish Mfg. Corporation

Bodies, Passenger Car
Baker R & L Co.
Mullins Body Corporation
Murray Body Corporation

Bodies, Steel
Mullins Body Corporation

Bolts, Connecting-Rod, A5
*Ferry Cap & Set Screw Co.
*National Acme Co.
*Steel Products Co.

Bolts, Eye
Williams & Co., J. H.

Bolts, Hexagon Head, C2
*National Acme Co.

Bolts, King
Ferry Cap & Set Screw Co.
Steel Products Co.

Bolts, Spring-Center, H4
*National Acme Co.

Bolts, Spring Shackle
Bowen Products Corporation
Ferry Cap & Set Screw Co.
Steel Products Co.

Bolts, Tie-Rod
Ferry Cap & Set Screw Co.
Steel Products Co.

Brackets, Fender
Murray Mfg. Co., J. W.
Parish Mfg. Corporation
Smith Corporation, A. O.

Brackets, Running-Board, H23
Crosby Co.
Murray Mfg. Co., J. W.

Brakes, Air
Westinghouse Air Brake Co.

Brake-Bands
Bossert Corporation
Diamond State Fibre Co.

Brake-Drums
Bethlehem Steel Co.
Bossert Corporation
Crosby Co.
Smith Corporation, A. O.

Brake-Hose Assemblies, Hydraulic
Hydraulic Brake Co.

Brake-Lining, C53
*Russell Mfg. Co.

Brakes
Bendix Brake Co.

Brass Alloys, B106
*Dole Valve Co.

Breakers, Circuit
Dayton Engineering Laboratories Co.

Bronze Alloys, D108
*Dole Valve Co.

Buckram, Leather
Carter Co., George R.

Bulbs, Incandescent Lamp, B5
*Brown Mfg. Co., Jno. W.

Bumpers, Passenger Car, C55
*Biflex Corporation
*C. G. Spring & Bumper Co.
*Stewart-Warner Speedometer Corporation

Bushings, Babbitt
Federal-Mogul Corporation

Bushings, Bronze
Bunting Brass & Bronze Co.
Dole Valve Co.
Federal-Mogul Corporation
Mueller

Bushings, Composition
Diamond State Fibre Co.
Formica Insulation Co.

Bushings, Drill Jig
Ex-Cell-O Tool & Mfg. Co.

Buttons, Electric Push
General Phonograph Mfg. Co.

Cabs, Motor Truck, L52
Highland Body Mfg. Co.
Murray Body Corporation

Cable, Insulated, B33
Bosch Magneto Co., Inc., Robert
General Electric Co.
Kerite Insulated Wire & Cable Co.
Western Electric Co.

Cables, Starting-Motor, B21
Western Electric Co.

Camshafts
Canton Drop Forging & Mfg. Co.
Park Drop Forge Co.
Wyman-Gordon Co.

Caps, Hub
Bossert Corporation
Crosby Co.

Caps, Radiator, C58a
*Stewart-Warner Speedometer Corporation

Caps, Tank, C58a
Akron-Selle Co.
Stewart-Warner Speedometer Corporation

Carburetor Controls, Automatic
*Dole Valve Co.

Carbureters, Cast Iron, A8
*Byrne, Kingston & Co.
*Stewart-Warner Speedometer Corporation

Carbureters, A8
*Bryne, Kingston & Co.
*Stewart-Warner Speedometer Corporation
Stromberg Motor Devices Co.

Carpet
Wiese & Co., Inc., Wm.

Casings, Radiator
Bossert Corporation
Mullins Body Corporation

Castings, Aluminum, D104
Doehler Die-Casting Corporation
*Franklin Die-Casting Corporation
*Light Mfg. & Foundry Co.
Milwaukee Die-Casting Co.
Scovill Mfg. Co.

Castings, Brass, D106
Doehler Die-Casting Co.
*Franklin Die-Casting Corporation
*Light Mfg. & Foundry Co.
Milwaukee Die-Casting Co.
Mueller
*Scovill Mfg. Co.
Stewart Mfg. Corporation

(Continued on page 90)

EXPLANATION OF SYMBOLS

Parts and materials followed by key numbers have been standardized by the S. A. E. The numbers refer to S. A. E. HANDBOOK data sheets on which each standard is published.

*Companies whose names are preceded by an asterisk supply the parts or materials under which the company is listed as conforming with the S. A. E. Standard referred to.

**Parts and materials followed by two asterisks indicate that two or more S. A. E. Standards are applicable. Information as to standards incorporated should be obtained from the manufacturer.

The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 94.

CLARK AXLES

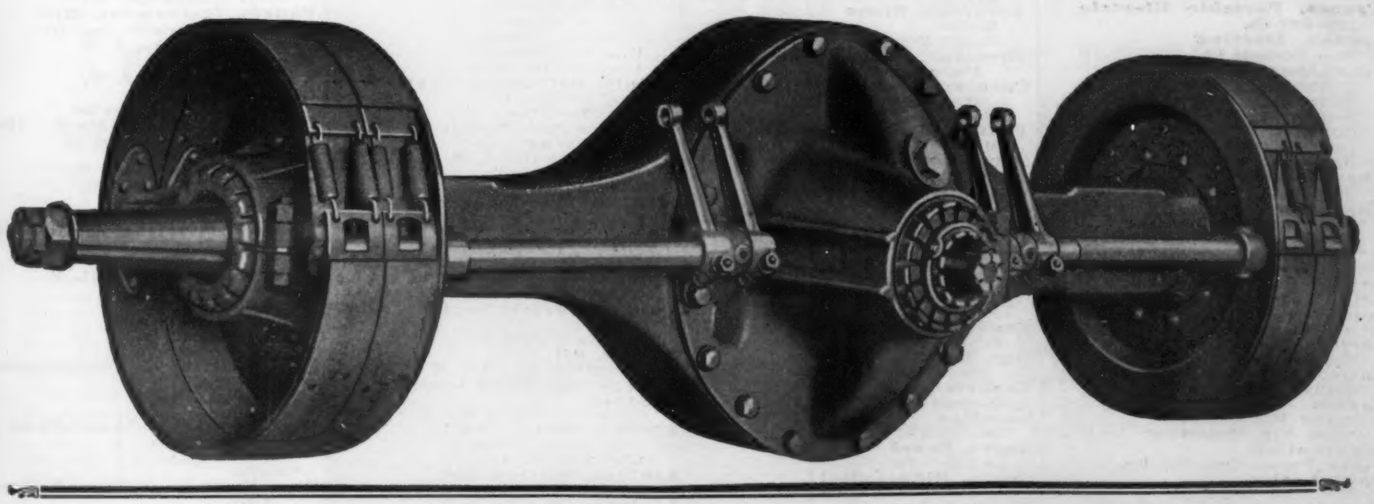
Double Wheel Bearings

Dual wheel bearings are used on the driving shafts of the heavier models of Clark Axles. These dual bearings eliminate pounding thrusts on the inner ends of the drive shafts ordinarily taken on thrust buttons.

Dual wheel bearings also permit closer adjustment of bearings as it is not necessary to allow clearance for shaft expansion under varying changes of temperature.

—just another reason why Clark Axles are known as good axles.

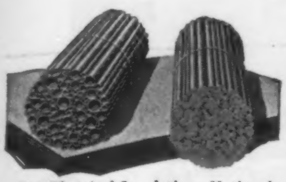
Clark Axles are Built by
CLARK EQUIPMENT COMPANY
BUCHANAN, MICH.



We also make Electric Furnace Steel Automotive Castings; all our Steel is Bottom Poured

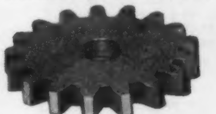
INDEX TO ADVERTISERS' PRODUCTS

(Concluded on page 92)



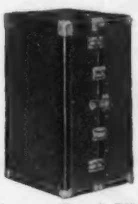
For Electrical Insulation, National Vulcanized Fibre . . . in Sheets Rods, Tubes and Special Shapes.

VUL-COT Baskets of National Vulcanized Fibre



For Silent Gears National Vulcanized Fibre

For Veneer Cauls National Vulcanized Fibre



Keystone Trunk Fibre is National Vulcanized Fibre

Laminar Mill Trucks and Roving Cans—made of National Vulcanized Fibre

?

Where next

Because of its toughness and lightness; because it can be readily bent and formed, sawed, tapped and threaded, milled, punched and turned; and again because of its high tensile strength, shearing strength and dielectric strength—National Vulcanized Fibre has become a part of every industry . . . What next? . . . Whatever it is, put it up to National Vulcanized Fibre. We maintain an organization of chemists devoted solely to work with customers and prospective customers.

We operate six great plants and maintain sales and service offices at New York, Boston, Philadelphia, Pittsburgh, Cleveland, Chicago, Los Angeles, San Francisco, Detroit, Rochester, Birmingham, Denver, Toronto, Greenville, St. Louis and Baltimore. National Vulcanized Fibre Company, Wilmington, Delaware.

INDEX TO ADVERTISERS' PRODUCTS

The Index to Advertisers is given on page 94

INDEX TO ADVERTISERS

An index to advertisers' products is given on pages 88, 90 and 92,


WATSON
STABILATOR
WATSON
COMPANY